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THE

KANSAS UNIVERSITY SCIENCE BULLETIN

DEVOTED TO
THE PUBLICATION OF THE RESULTS OF
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Vol. XX

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S-A-L

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THE UNIVERSITY OF KANSAS
SCIENCE BULLETIN

VOL. XX.] MAY 15, 1931. [No. 1.

The *Rhagovelia* of the Western Hemisphere, with Notes on World Distribution (Hemiptera, Veliidæ).*

GEORGE E. GOULD,
Department of Entomology, University of Kansas.

INTRODUCTION.

THE broad-shouldered water-striders is the common name given to the insects belonging to the genus *Rhagovelia*. This is a group of small aquatic Hemiptera which spend their lives on the surface of our fresh-water streams. Due to their small size and their habitat, few collectors take them, or even see them. Often these striders are mistaken for their larger relatives, the gerrids, as the two are frequently found skating together on rapid-moving streams.

The genus *Rhagovelia* may be easily distinguished by five characters: the 4-segmented antennæ, the 3-segmented beak, the 3-segmented tarsi, the basal antennal segment longest, and the third tarsal segment of the intermediate leg split three-fourths of its length and with feathery hairs in this cleft. The individuals vary in size from 2.5 mm. to 8.5 mm. and in color from yellowish-brown to black.

The habitat of these small bugs is rapid-moving streams, with the exception of three species which live on the salt water of bays. They are gregarious: groups may be found in the eddies of streams, where they are presumably awaiting the arrival of food which the current brings them. Although the *Rhagovelia* are predators, they usually will not attack another of their kind, nor will they molest the larger gerrids that are often found in the same pool. They are

* Submitted to the Department of Entomology and the Faculty of Graduate School of the University of Kansas in partial fulfillment of the requirements for the degree of M. A., May 6, 1929.

excellent divers and can swim readily below the surface of the water. Bueno (1907) says, "Mating takes place in June or July, when the schools are made up largely of sexes *in copula*."

Both winged and wingless forms are found together, the wingless forms being more common. That the winged forms are good flyers is shown by the fact that Doctor Beamer in 1927 collected two specimens from a water tank in Arizona forty miles from any running water. Usually the number of males and females found in a school is about equal.

HISTORICAL.

The genus *Rhagovelia* was erected in 1865 by Mayr for three species described by Burmeister in 1835 in the genus *Velia*. Uhler was the first to describe a species from the United States, describing the well-known form *obesa*, in 1871. In 1879 F. B. White erected the genus *Neovelia* for the species *trailii*, which later proved to be a *Rhagovelia*. In 1894 Uhler added two more species and in 1898 Breddin described *Neovelia whitei*, which was later assigned to *Rhagovelia*.

Then in 1898 Champion more than doubled the number of the then known species by his addition of nine new species from Central America. About the same time Kirkaldy described two species and in 1900 published a check list of the nineteen species known from the Western Hemisphere. Since then several writers have added to our knowledge of the group, three of the more recent writers being Bueno and Drake & Harris, who described three species and six species respectively.

DISTRIBUTION.

Specimens of *Rhagovelia* are not common in our museums. Due to their small size, their color, and their habitat, only the specialists on aquatic and semiaquatic Hemiptera have made any appreciable collections of them. The insects are probably widely distributed throughout this country, South America, Central America, and the West Indies.

Rhagovelia seem to be typically a Western Hemisphere group, as forty-five species of a total of fifty-one are from this half of the world. None has been reported from Europe. Some day, perhaps, there may be collectors in the Eastern Hemisphere that will prove that part of the world equally important as a home of the *Rhagovelia*.

Records of all species as far as known are given in this paper for the sake of completeness. Included here are fifty-one species and eight varieties. Of this number thirteen species and eight varieties are described as new to science. One species, *R. reitteri* Reuter from Addah, is omitted, this making a total of fifty-two known species in the world.

DISTRIBUTION OF THE WORLD SPECIES.

	Africa.	Asia.	Australia.	East Indies.	West Indies.	Central America.	South America.	North America.
æneipes Hag				×				
amazonensis n. sp							×	
angustipes Uhler					×	×	×	×
arctoa Bueno								×
armata (Burm.)								×
australica Kirk			×					
bakeri Bergroth						×		
beameri n. sp								×
calopa D. & H						×		
castanea n. sp							×	
chorcutes Hussey								×
collaris (Burm.)					×			
var. *planipes* n						×	×	
var. *pulchra* n					×			
confusa n. sp							×	
crassipes Champ						×		
distincta Champ								×
new varieties:								
arizonensis n. var								×
cadyi n. var								×
harmonia n. var								×
proxima n. var								×
modesta n. var								×
valentina n. var								×
elegans Uhler					×			
femoralis Champ						×		
festæ Kirkaldy							×	
flavicincta Bueno								×
gigantea Gould							×	
gregalis D. & H						×		
hirtipes D. & H						×		
insularis Champion					×	×	×	
knighti D. & H								×
longipes n. sp							×	
lucida n. sp							×	
maculata Distant	×							
nigricans (Burm.)	×	×						
obesa Uhler								×
obscura n. sp							×	
oriander Parshley								×
peggiæ Kirkaldy				×				
plumbea Uhler					×			×
ravana Kirkaldy		×						
regalis D. & H						×		
relicta n. sp							×	
rivale Bueno								×
robusta n. sp							×	
salina Champion					×	×		
sinuata n. sp							×	
spinigera Champ						×		
spinosa n. sp							×	
tarloriella Kirk					×			
tenuipes Champ								×
trailii (White)							×	
trista n. sp							×	
uncinata Champion						×		
varipes Champion								×
virida (White)						×		
whitei (Breddin)							×	
williamsi n. sp							×	
Totals: Species	2	2	1	2	7	13	18	14
Varieties					1	1	1	6

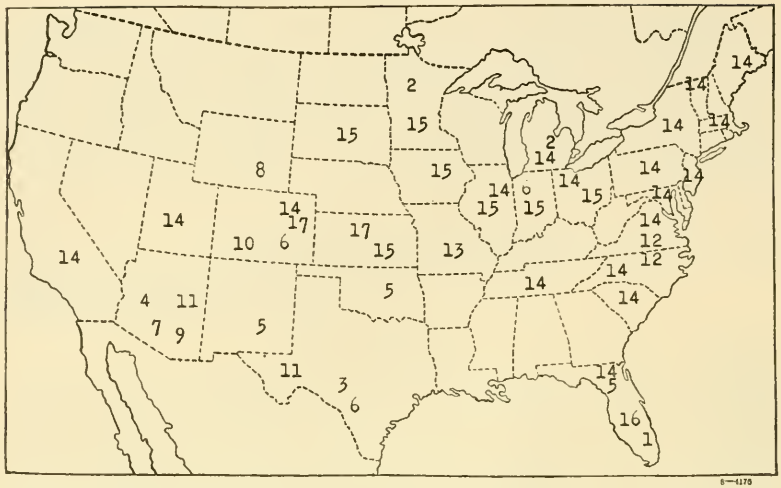

FIG. 1.—Distribution of species of *Rhagovelia* by States in the United States.

Numbers refer to species: 1, *angustipes* Uhler. 2, *arctoa* Bueno. 3, *armata* (Burm.). 4, *beameri* n. sp. 5, *choreutes* Hussey. 6, *distincta* Champ. 7, d. var. *arizonensis* n. var. 8, *d.* var. *cadyi* n. var. 9, *d.* var. *harmonia* n. var. 10, *d.* var. *proxima* n. var. 11, *d.* var. *valentina* n. var. 12, *flavicincta* Bueno. 13, *knighti* D. & H. 14, *obesa* Uhler. 15, *oriander* Parsh. 16, *plumbea* Uhler. 17, *rivale* Bueno.

CLASSIFICATION.

FAMILY VELIIDÆ Am. & Serv. 1843.

(After Hungerford.)

"*Family Characteristics.* Surface dwellers which are usually plump bodied, and broadest at the shoulders. The antennæ are 4-segmented, and the head is shorter than the thorax, including the scutellum. The middle legs are placed about equidistant from the front and hind pairs (except in *Rhagovelia*). The hind femora do not extend much beyond the apex of the abdomen. The ocelli are obsolete or absent. Beak 3-segmented; tarsi 1 or 2-segmented in front, and 2 or 3-segmented in the others. Most of these bugs are small."

KEY TO THE GENERA.

A. Last antennal segment longest.
  B. Ocelli in contact with inner margin of eyes.....*Macrovelia.*
  BB. Ocelli absent .....*Microvelia.*
AA. First antennal segment longest.
  B. Third segment of middle tarsus split and with feathery hairs set in slit, *Rhagovelia.*
  BB. Intermediate tarsi not split.....*Velia.*

GENUS RHAGOVELIA Mayr.

Rhagovelia Mayr, 1865, Verh. Zoöl.-bot. Ges. Wien, 15:445.
Baccula Stal, 1865, Hem. Afr., 3:157.
Neovelia White, 1879, Jour. Linn. Soc. Lond., Zoöl., 14:487.
Trochopus Carpenter, 1898, Ent. Mo. Mag., 34:78.

The original description by Mayr is as follows:

"*Veliæ proxima.* Caput antice truncatum infra retractum; oculi approximati. Tarsi antici breves triarticulati, articulis 1 et 2 brevissimis globulosis,

articuli apicali fusiformi, infra medio exciso biunguiculato, tarsi intermedii triarticulati posticis triplo longiores, articulo basali minutissimo, secundo longo cylindrico, apicali secundo longo cylindrico, apicali secundo æquilongo, subfusciformi, ab apice ad basin fissura longitudinali, e qua oriuntur unguiculi 2 longissimi parum curvati."

The genus may be quickly characterized by five structures: 4-segmented antennæ, the 3-segmented beak, the 3-segmented tarsi on all legs, the basal antennal segment longest, and the third tarsal segment of the intermediate leg split three-fourths of its length and with feathery hairs in this split. The largest known specimen is 8.5 mm. in length and over 2 mm. wide across the pronotum, while the smallest species is about 2.5 mm. in length.

STRUCTURAL CHARACTERS USED IN CLASSIFICATION.

The outstanding peculiarity of the genus is the condition of the third tarsal segment of the middle leg. This segment is split for three-fourths of its length and provided with about twenty plumose hairs arising from the base of the cleft. The purpose of these hairs is to support the insect upon the surface of the water, the hairs being spread out fanlike. The hairs are also used for swimming under water. See the drawing of this segment in plate V, fig. 12.

Another peculiarity present among some members of the genus is the sutured-off pronotum. This condition is found among a group of small South American forms (and *tenuipes* from Mexico), these forms probably being more primitive. Among most species the pronotum is as broad as long with a small, or even completely hidden, mesonotum. In this primitive group the pronotum is one-third as long as wide, and the mesonotum is longer than the pronotum, the suture between the two being straight and distinct. To this group belong twelve or even more of the known species.

Of the many characters used in classification the presence of a curved hook at the apical tip of the posterior tibiæ has proven one of the more distinct. Three species have the posterior tibiæ armed with this definite hook, while the remainder may, or may not, have a straight spur at the apex. The function of the hook or spur is unknown, but in all probability it is unimportant.

A character recently used in many groups of insects, including the *Rhagovelia,* is the proportion existing between the measurements of one part of the body and those of another part. In the present paper the proportional lengths of the antennal and leg segments are used. Although individuals may show a slight variation, the character is considered of sufficient importance to justify its use and can

be depended on if several specimens are examined. For the sake of brevity, the antennal formula (segment 1, seg. II, seg. III, seg. IV) and the leg formulæ (femur, tibia, tarsal seg. II, tar. seg. III) are omitted from further statement. All formulæ given belong to the original authors by direct quotations or by interpretation of the original description.

Valuable characters are found in the segments of the posterior legs. The femur is sometimes thickened or swollen to an enormous size, that of the male always being larger than that of the female. The size of the hind femur is subject to wide variation, ranging from enormously incrassate to normal within certain species. In which case the hind tibia may vary from strongly curved to straight, the amount of curvature accompanying the extent of the incrassate condition of the femur. On the inner or posterior side of the femur there are usually numerous spines arranged in distinct groups according to the species. The tibia is usually denticulate, the species varying in this respect from none to arrangements of one or two rows, and sometimes having one to three longer spines. The apex of the tibiæ is frequently armed with a curved hook or a straight spur. On the larger specimens the coxæ and trochanters may be armed with minute teeth also. The females and the winged forms always have less armature than the apterous males.

GENITALIA.

Characters found in the genitalia are now being used by workers in many insect orders. The genitalia of the *Rhagovelia* have proved valuable in separating groups and even the species discussed in this paper. The present work is not a morphological discussion of these characters, but refers to the genitalia only for their taxonomic value. All drawings are from the male sex.

Two papers that have been very useful in this study are those on the genitalia of *Rhynchota* by Singh-Pruthi in England and Ekblom in Sweden. Since both papers were written about the same time, neither author had the benefit of referring to the other and therefore their explanations and terminology differ in some respects. I have followed both in part, but in most cases have adopted the terminology of Ekblom.

According to Singh-Pruthi the abdomen of a hemipterous insect consists of ten almost complete segments, the ninth being modified to bear the genitalia. This ninth segment, called the hypandrium, is spoon-shaped and much enlarged. Segment ten (the "anal lid" of Ekblom) is a long, more or less tubular structure covering the open

ninth segment, and consists of two parts: the supra-anal plate over, and the podical plate under, the anal tube (see Pl. I, Fig. 3). In some species of *Rhagovelia* the supra-anal plate is modified on its dorsal surface by having two or three posteriorly projecting "horns."

Externally the parts of the genitalia visible are the hypandrium, the supra-anal plate, and the claspers (the "parameres" of Singh-Pruthi, and "copulation hooks" of Ekblom). The claspers are simple, bent at an angle inwardly, with a slight convexity on the inner side at the point of curvature, and at rest extended toward the center in a protecting manner over the genital opening. In all species the claspers are covered with numerous small and a few large hairs, and are frequently pointed. The hypandrium may be modified by depressions on its ventral surface and by prolongation.

If the anal lid is removed, the internal genitalia is exposed (Pl. I, Fig. 4). In the center is the penis which is attached at its lower posterior surface to two points of a broad, semicircular membrane, the lever (after Ekblom, the "basal plates" of Singh-Pruthi). To the lever are attached the various muscles for protraction and retraction of the penis, the lever itself being attached to the hypandrium by a tendon at the same point as the claspers (at *x*, in Pl. I, Fig. 4).

On removing the penis and the lever (Pl. I, Fig. 2), we see that the penis is an obovate, slightly "chitinized" structure. On further examination and dissection it is found that there are two sections of a faintly "chitinized" membrane surrounding a membranous ovoid body (probably the "swell-body" of Ekblom). In the central body are an unpaired and two paired structures, more strongly chitinized and probably the "vesica appendages" mentioned by Singh-Pruthi. Into one pair of these appendages (*pa 1*) enter the branched ejaculatory ducts.

In the present study the claspers of the male have proven to be distinctive for each species in many cases. Whenever possible a drawing was made of the clasper of all species of *Rhagovelia* obtained. Where the claspers of closely related groups appeared to be similar, an appendage of the penis (*pa 1*) has been satisfactorily used for specific determinations.

DETERMINATIONS.

Dr. H. B. Hungerford, under whose direction this work was undertaken, spent eight months of 1928 in Europe, studying type material in all important European museums. He carried with him several thousand specimens, representing all groups of aquatic and

semiaquatic Hemiptera in the University of Kansas Museum and many from the Smithsonian Institute. Among the material were over one hundred specimens of *Rhagovelia,* representing every group at hand. These specimens were compared with types and general material in the British Museum, the Berlin Museum, and the Museum of Vienna. Besides comparison with types, Doctor Hungerford made notes on type and other specimens discovered in the foreign museums. He found eleven unnamed specimens of *R. gigantea* Gould, for the description of this species then had not been published. These specimens were loaned to Doctor Hungerford through the courtesy of Doctor Horvath, and much new material was obtained in England.

Determinations in this paper are based, whenever possible, on the observations of Doctor Hungerford in Europe, credit being given him under each species. Other determinations were made from type material in this country and from published descriptions.

The writer is greatly indebted to Doctor Hungerford, under whose direction this work has been completed, especially for his helpful suggestions and his examinations of European types. The writer is also indebted to Dr. P. J. Chapman, of the Virginia Truck Experiment Station, for his helpful suggestions and criticisms in completing this work.

KEY TO THE SPECIES OF RHAGOVELIA OF THE WESTERN HEMISPHERE.*

1.	Posterior tibia armed at apex with a hook	2
	Posterior tibia with or without a distinct spur	4
2.	Terminal genital segment mucronate	*uncinata* Champ.
	Terminal genital segment not mucronate	3
3.	Pronotum fuscous; posterior femur armed with seven long teeth, the two inner ones longer and thicker	*elegans* Uhler.
	Pronotum rufo-castaneous; posterior femur armed with five or six long teeth, the first, second and fourth longest, the first and second being a little more distant than the others	*insularis* Champ.
4.	Pronotum sutured-off from mesonotum in apterous forms	5
	Pronotum not sutured-off from mesonotum	16
5.	Antennal segment III as long as II and longer than IV	6
	Antennal segment III shorter than II or IV	14
6.	Tarsal segment II of intermediate leg much longer than segment III	7
	Tarsal segment II less than, equal to, or only slightly longer than segment III	9
7.	Posterior femur unarmed	8
	Posterior femur armed with one long and three or four short teeth	*tenuipes* Champ.
8.	Legs long; posterior tibia much longer than the femur	*longipes* n. sp.
	Legs normal in length	*plumbea* Champ.
9.	Tarsal segment II of intermediate leg less than III	10
	Tarsal segment II equal to, or greater than III	11

* This key is in part copied after Champion and Bueno, but additions and rearrangements have been made, so that most of the work is original. Four species have been left out, due to the fact that the descriptions are inadequate for obtaining characters distinctive enough to use in a key. These species are *hirtipes* D. & H., *trailii* (White), *whitei* (Breddin), and *vivida* (White). Notes are listed under each of these species. *Excellentis* D. & H. is also omitted, being listed as a synonym of *distincta* Champion.

10. Posterior femur armed with one long and three short teeth.....*spinosa* n. sp.
Posterior femur armed with one long and eight to ten short teeth....*angustipes* Uhler.
11. Apex of posterior tibia armed with straight spur..... 12
Apex of posterior tibia unarmed.....*gregalis* D. & H.
12. Connexivum of female abruptly rounded and clothed at apex with longer hairs; antennal segments II and III equal; posterior tibia equals femur.....*regalis* D. & H.
Connexivum without longer hairs at apex; antennal segments II and III unequal; posterior tibia unequal in length to femur..... 13
13. Anterior tibia with groove; posterior tibia with serrate teeth throughout..*obscura* n. sp.
Anterior tibia without groove; posterior tibia slightly sinuate and with only a few small teeth.....*confusa* n. sp.
14. Posterior femur of male enormously incrassate.....*calopa* D. & H.
Posterior femur normal or slightly incrassate..... 15
15. Posterior femur unarmed.....*festa* Kirk.
Posterior femur armed.....*salina* (Champ.).
16. Pronotal length of apterous form not to exceed ⅝ the width exposing much of the mesonotum 17
Pronotal length subequal to or greater than the width..... 18
17. Antennal segment I thickened and segment III club-shaped.....*lucida* n. sp.
Antennal segments normal.....*trista n. sp.*
18. Anterior tibia strongly dilated especially in male (greatest width about ¼ length); connexivum of female much narrowed in from the base at first, afterwards continuing subparallel..... 19
Anterior tibia not strongly dilated; connexivum reflexed or vertical, and parallel..... 22
19. Posterior tibia sinuate in the male*..... 20
Posterior tibia straight..... 21
20. Posterior femur armed with regular teeth, and posterior tibia slightly sinuate in the male with regular teeth.....*collaris* (Burm.).
Posterior femur greatly incrassate, armed with several large teeth; posterior tibia strongly sinuate and armed with a stout spine at apical two-fifths.....
collaris var. *planipes* n. var.
21. Antennal segment I twice as long as segment II.....*collaris* var. *pulchra* n. var.
Antennal segment I not twice as long as segment II.....*tayloriella* Kirk.
22. Intermediate femur constricted at middle.....*spinigera* Champ.
Intermediate femur not constricted..... 23
23. Posterior femur of male strongly incrassate (width ¼ to ⅖ of the length) and dentate; posterior tibia also strongly dentate..... 24
Posterior femur of male slightly or moderately incrassate (width less than ¼ of the length)..... 33
24. Intermediate tarsal segment II shorter than III..... 25
Intermediate tarsal segment II longer than III.....*varipes* Champ.
25. Posterior femur of male with large, stout tooth at apical third, preceded by five stout teeth; length 8 mm.....*gigantea* Gould.
Posterior femur not so armed; length 7 mm. or less..... 26
26. Denticulations on posterior tibia of male regular..... 27
Denticulations on posterior tibia with some large teeth..... 29
27. Tarsal segments of intermediate leg longer than tibia.....*bakeri* Berg.
Tarsal segments of intermediate leg equal to or shorter than tibia..... 28
28. Posterior tibia longer than femur.....*beameri* n. sp.
Posterior tibia shorter than femur.....*sinuata* n. sp.
29. Posterior tibia of male denticulate and with three long teeth.....*crassipes* Champ.
Posterior tibia with only one long tooth..... 30
30. Posterior tibia of male straight*.....*femoralis* Champ.
Posterior tibia sinuate..... 31
31. Posterior femur of male armed with two irregular rows of teeth and one large tooth on the middle above.....*robusta* n. sp.
Posterior femur armed otherwise..... 32
32. Posterior femur of male armed with a row of six large spines, the second being the longest, and also one large spine on the lower surface.....*castanea* n. sp.
Posterior femur armed with two irregular rows of teeth, the first and third being the longest .....*relicta* n. sp.

* See discussion on page 10.

33. Length 8 mm. or more.....*gigantea* Gould.
Length 7 mm. or less..... 34
34. Apterous female with connexivum vertical and male usually flat and broad..... 35
Apterous female with connexivum reflexed..... 39
35. Connexivum of apterous female much narrowed in from base at first, afterwards continuing subparallel..... 36
Connexivum subparallel, or gradually tapering posteriorly..... 37
36. Connexivum of female ending in stout blunt spine; posterior femur of male armed with about nine spines in two rows.....*williamsi* n. sp.
Connexivum of female not projecting apically; posterior femur of male with seven spines in single row.....*amazonensis* n. sp.
37. Posterior tibia sinuate; anterior tibia normal..... 38
Posterior tibia straight; anterior tibia dilated.....*armata* Champ.
38. Posterior femur with a regular row of teeth.....*beameri* n. sp.
Posterior femur with two rows of teeth and with one large tooth at basal third and another at the middle.....*sinuata* n. sp.
39. Intermediate tibia twice as long as third tarsal segment; connexiva in female not meeting above the abdomen.....*rivale* Bueno.
Intermediate tibia less than twice as long as third tarsal segment..... 40
40. Pronotum produced into a spiniform process..... 41
Pronotum not produced into a spiniform process..... 44
41. Pronotum of apterous forms with spiniform process.....*oriander* Parshley.
Pronotum of winged forms only with spiniform process..... 42
42. Tip of pronotal spine expanded and emarginated.....*obcsa* Uhler.
Tip of pronotal spine of normal width..... 43
43. Posterior femur equal to or longer than tibia; length of body about 5 mm. ..... *distincta* Champ.
Posterior femur shorter than tibia; length 4 mm.....*chorentes* Hussey.
44. Connexiva of female diverging caudally over the last abdominal segment..... *distincta* Champ.
Connexiva of female close together or meeting at distal end..... 45
45. Pronotum of apterous female armed with a long spiniform process; pronotum of apterous male sharply pointed posteriorly.....*oriander* Parshley.
Pronotum of apterous forms not produced posteriorly..... 46
46. Anterior trochanter of male armed with a black spine..... 47
Anterior trochanter unarmed..... 48
47. Tarsal segments II and III of intermediate legs subequal; length 3.8-4.4 mm..... *arctoa* Bueno.
Tarsal segment III longer than II; length 3.2 mm.....*knighti* Drake and Harris.
48. Posterior tibia longer than femur.....*chorentes* Hussey.
Posterior tibia subequal to or shorter than femur..*flavicincta* Bueno* and *obesa* Uhler.

LIST OF THE SPECIES OF RHAGOVELIA OF THE EASTERN HEMISPHERE.

æneipes Haglund:
1895. Ofv. Ak. Forh., p. 476. Habitat: Guinea.

australica Kirkaldy, G. W.:
1908. Sydney Proc. Linn. Soc., 32:783. Habitat: Queensland.

insignis Distant:
1903. Fascic. Malay. Zoöl., I:256. Habitat: Malay. Referred to *Microvelia*. New combination.

maculata Distant:
1903. Ann. Mag. Nat. Hist., (7):12:472. Habitat: Nigeria (Africa).

nigricans (Burmeister):
Velia nigricans Burmeister—
1835. Handbuch der Entomologie, 2:212.
Rhagovelia nigricans Mayr—
1865. Verh. Zoöl.-bot. Ges. Wien, XV, p. 445. Habitat: Africa. New records: Egypt, Ceylon, and Seychelle Islands.

* The apterous forms of these two species are too close together to key out. In *R. obesa* Uhler the first segment of the antenna appears to be relatively longer than the fourth in comparison with *R. flavicincta* Bueno.

peggiæ Kirkaldy:
1901. Ann. Mus. Genova. 40:805. Habitat: New Guinea.

ravana Kirkaldy:
1901. Entomologist p. 209. Habitat: Ceylon.

reitteri Reuter:
Ofv. Fin. Soc., 25:39. Habitat: Addah.

RHAGOVELIA OF WESTERN HEMISPHERE.

Rhagovelia amazonensis n. sp.

Antennæ: 20:12:12:12.
Intermediate legs: 44:33:13:19.
Posterior legs: 36:28:2:8.

General color dark brown, sometimes lighter; clothed with yellow pubescence. Pronotum with narrow, transverse, light brown or yellow band across anterior margin. All coxæ, anterior trochanters, intermediate and posterior trochanters in part, the acetabula in part, base of anterior and posterior femora, base of antennæ, and edge of connexivum, light brown. Pronotum obtusely rounded behind, covering the mesonotum; metanotum slightly emarginate behind. Venter varying from grayish-black to brown with gray sutures. Anterior trochanters unarmed; posterior tibia armed at apex with a spur.

Apterous Male. Connexiva broader at the center, tapering slightly anteriorly and posteriorly. Posterior trochanter armed on inner side with one stout spine. Posterior femur slightly incrassated, armed at basal third with a long spine, followed by six small, stout spines.

Apterous Female. Abdomen broad, subparallel. Connexiva nearly vertical. First and fourth dorsal segments of the abdomen gray; segments two with numerous long fine hairs. Posterior femora much as in the male, with the spines a trifle longer. Connexiva and abdomen ending with numerous stiff hairs. First genital segment flat and obtusely rounded; below with median carina. Posterior tibia sinuate, denticulate on the posterior margin and armed at apex with a long stout spur.

Length, 3.5-3.7 mm.; width, 1.15 mm.

Holotype, apterous male; allotype, apterous female; paratypes, forty apterous females. All from Solimoes river, Manacapuru, Amazonas, Brazil. April, 1926; S. M. Klages. All types are in the University of Kansas collection.

Comparative Notes. This species is similar to *R. williamsi* n. sp., even the male claspers being similar in shape, but differing in size. The connexiva gradually decreases in size posteriorly in this species, while in *williamsi* each connexivum ends in a sharp spinelike projection.

Rhagovelia angustipes Uhler.

R. angustipes Uhler. Proc. Zoöl. Soc. Lond., p. 215, 1894.
R. angustipes Champion. 1898. Biol. Cent.-Amer., Het., Vol. 2.
R. angustipes Kirkaldy. 1900, Ent., 34:308.

A small black species similar in form to *R. obesa* Uhler. Antennal segment I longer than II, segment II and segment III subequal in length. Pronotum sutured off from mesonotum and trapezoidal in front of humeral angles; mesonotum triangular. Posterior femora slightly thickened and armed beneath

with a row of fine teeth; tibia clothed with many stiff hairs. Genital segments and the last abdominal segment in the center are orange in color.

Length, 3 to 3½ mm.; width, 1¼ mm.

Notes. Four specimens from Tena, Ecuador, were compared with the type by Doctor Hungerford and determined to be the same. These specimens differ from the description given in having the pronotum sutured off from the mesonotum. However, this variation in *R. angustipes* was noted by a previous writer.

Further description of the Ecuador specimens:

Antennæ: Male, 20:11:13:13; female, 20:10:12:13.
Intermediate legs: 42:28:13:19; 41:27:12:20.
Posterior legs: 34:34:4:9; 32:33:4:9.

Apterous Male. Genital segments large. Posterior femur slightly incrassate, being about equal to intermediate femur at base; armed with one tooth at the apical two-fifths, followed by 8 or 10 short teeth. Posterior tibia armed only with slender spur at apex. Venter with distinct median carina, the last segment depressed slightly on each side.

Apterous Female. Dorsum of last five abdominal segments with shining black spot; dorsum humped on the first and second segments. Posterior femur armed with one tooth at apical third, followed by four, and possibly more, minute teeth.

Distinguished from related species by shorter second tarsal segment, by antennal proportions, and the male clasper.

Distribution Records. Mexico, Panama, St. Vincent, Grenada, and Venezuela. New record: Ecuador.

Rhagovelia arctoa Bueno.

R. arctoa Bueno. Trans. Amer. Ent. Soc., 50:243-252, 1924.

Antennæ: Male, 16:9:10:9; female, 17:10:9:8.
Intermediate legs: 35:25:15:15.
Posterior legs: 25:22:3:5; 28:25:3:7.

A small black species similar in form to *R. obesa* Uhler. Original description is as follows:

"*Males, Apterous.* Femoral spine not very slender, straighter, followed by six blunt spines, stouter in comparison, more prominent; femoral spine three-fifths length of femur from apex; posterior tibia denticulate; posterior tars. seg. II: seg. III:: 3:6; anterior trochanters with a stout black spine on the outer aspect; abdominal segments two to five subequal, six twice as long as the preceding one.

"*Females, Apterous.* Pronotum posteriorly sinuately truncate, feebly carinate longitudinally. Posterior femora with a sharp curved spine followed by smaller ones, as in male; not much stouter than intermediate femora. Anterior trochanters without a spine; connexivum reflexed, meeting above last abdominal segment and terminating acutely in two long divaricating spines; genital segment trapezoidal, polished above; edge of first segment of connexivum with long hairs appressed to form a seeming spine."

Length, 3.8-4.4 mm.; width, 1.1-1.4 mm.

Types are in the collections of the University of Kansas, W. E. Hoffman, H. M. Parshley, J. R. de la Torre Bueno, and the American Entomological Society.

Notes. This species, of which the type and thirteen paratypes as well as 150 specimens collected by Dr. H. B. Hungerford at the type locality, has been carefully studied and found to be very close to *R. obesa* Uhler. The claspers of the two species are decidedly different, those of *arctoa* being much longer (long 7, wide over 3; *obesa,* long 5, wide 2½).

Externally the two species may be distinguished by the darker legs of *arctoa,* which lack the pale basal markings of the anterior femora, and the black coxæ and trochanters of the intermediate and posterior legs. In *obesa* the coxæ, trochanters, and the base of the anterior femora are marked with flavous.

Distribution Records. Minnesota, Michigan, and Ontario, Canada.

Rhagovelia armata (Burm.).

Velia armata Burmeister. Handb. der Ent., 2:212, 1835.
Rhagovelia armata Mayr. Verh. Zoöl.-bot. Ges. Wien, 15:445, 1867.
R. armata Champion. Biol. Cent.-Amer., Heter., 2:136, 1898.
R. armata Kirkaldy. Ent., 34:308, 1900.
R. armata Van Duzee. Check list of Hemiptera, N. Y. Ent. Soc., 1916.
R. armata Van Duzee. Cat. Hemi. Am. N. Mex., 1917.
R. armata Hungerford. Kan. Uni. Sci. Bul., XI, Dec., 1919.

The writer's description:

A large brownish-black species. Antennal segment I more than one-half longer than II, segments II and III subequal, segment IV less than III (32:20:20:18). Intermediate leg with tarsal segment III equal to II. Pronotum of winged form produced behind into a long spiniform process, that is armed beneath with a stout spine; pronotum of apterous forms abbreviated and rounded behind. Venter with segments I and II and the intercoxal portion of metasternum depressed. Anterior tibia dilated in outer half and grooved beneath. Posterior femora moderately incrassated, armed at middle with one long tooth and a row of short teeth extending thence to apex; posterior tibia slightly sinuate and faintly denticulate and armed at apex with a short straight spur.

Notes. Champion says that *R. armata* is nearest allied to *R. femoralis,* from which it differs in the more elongate body, the longer legs and antennæ, the less incrassate posterior femora in the male and the hind tibiæ without long teeth. Also near to *R. distincta.*

Length, 5¾ mm.; width, 2 mm.

Distribution Records. Mexico, Texas.

Rhagovelia bakeri Berg.

Rhagavelia bakeri Bergroth. Psyche, 21:74, 1914.

The writer's description:

A black species with antennal formula of 30:20:18:17. The tarsal segments of the intermediate leg a little longer than the tibia; second tarsal segment slightly shorter than the third. Last dorsal segment of male truncate at apex, last ventral segment arcuately emarginate. Posterior femora very strongly incrassate, armed near middle with a large tooth followed to apex by series diminishing in size. Posterior tibia straight, finely toothed beneath,

the teeth of the middle third slightly longer; armed at apex with short straight spur.

Length, 4 mm.

Notes. Similar to *R. femoralis* Champ., but differing in structure of antennæ, the venter not ridged, and the posterior tibia without large teeth.

Distribution Record. Nicaragua.

Rhagovelia beameri n. sp.

Antennæ: 46:28:32:26.
Intermediate legs: 88:72:31:37.
Posterior legs: 77:96:10:19.

General color blackish, with brown pubescence. Head with usual impressed lines. Antennæ, legs, and sides of body clothed with longer hairs, with a few scattered setæ (except on the two apical antennal segments). Base of antennæ, base of anterior femora, all coxæ, anterior and posterior trochanters, propleura, edge of connexivum, and two spots on the pronotum, brown. Venter black shading to brown posteriorly. Pronotum obtusely rounded in apterous forms. Anterior trochanters unarmed; posterior tibia with a stout spur.

Apterous Male. Posterior femora enormously incrassated, armed with numerous short teeth arranged in two regular rows, the upper row longer and with eight teeth, the lower row of minute teeth and extending nearly across the femur. Posterior tibia bowed inwards to beyond the middle and thence curved slightly outward to the apex, denticulation small near the base and increasing in size toward the apex. Connexivum broad but little reflexed. Sixth dorsal segment truncate at the apex. Genital segments and last abdominal segment clothed with bristly hairs. Venter carinated basally.

Apterous Female. Posterior femora slightly incrassate, a little thicker than the intermediate, and armed with three short spines and usually three minute spines on the apical third. Posterior tibia straight and unarmed. First genital segment set in between ends of connexiva and rounded posteriorly; ventrally with a distinct longitudinal suturelike groove. Connexiva semivertical. First ventral abdominal segment carinated.

Winged Forms. Much as in apterous forms. Posterior femora not so much incrassated. Pronotum of male and female long and bluntly angular (long 37, wide 35). Elytra extending beyond the tip of the abdomen.

Length, male, 6 mm.; female and winged forms, 6.3 mm.

Width, male and female, 1.8 mm.; winged forms, 2.3 mm.

Genitalia: The claspers of the male resemble no other specimen studied. Its size is nearly twice as large as any other North American species. (See plate III.)

Holotype, apterous male, Cochise county, Arizona, July 29, 1927, R. H. Beamer; allotype, apterous female, same data; morphotype, winged female, same data; paratypes, apterous males and females, same data; also one apterous female, Huachuca Mountains, Arizona, August 1, 1927, L. D. Anderson. All types are in the University of Kansas collection.

Comparative Notes. This species is very similar to *R. armata* (Burm.), being like it in color, size and the posterior legs. It differs from *armata* in the shape of the pronotum, which is produced posteriorly to an acute angle,

but not into a spiniform process (as in the winged forms of *armata*). Also the anterior tibiæ are not dilated in their apical half, and the posterior tibiæ are more sinuate.

This species is also close to *R. varipes* Champion, differing in having the second tarsal segment of the intermediate leg shorter than the third.

Rhagovelia calopa D. & H.

Rhagovelia calopa Drake & Harris. Proc. Biol. Soc. Wash., 40:131-138, 1927.

Antennæ: "31:18:13:16."
Intermediate legs: "64:47:23:28."
Posterior legs: "52 (wide 20):54:5:12."

The writer's description:

A small grayish-black species, with the pronotum distinctly sutured off from mesonotum; the latter is three and a half times longer than the former. Abdomen narrowed posteriorly; connexivum broad, strongly narrowed apically. Anterior trochanters unarmed. The posterior femur enormously swollen and armed with two rows of spines, the lower row shorter and continuing the length of the femur; the upper row of spines irregular, with a longer, stout spine at the basal third and one or two double spines near the middle. The posterior tibia have a double row of short, stout spines with one or two on the apical third very long; tibia armed at apex with a spur.

Length, 2.86 mm.; width, 1.5 mm.

Notes. This species is similar in appearance to *R. femoralis* Champion, but may be readily separated by its sutured-off pronotum. It differs from all specimens with this pronotal character by having enormously incrassated posterior femora.

Distribution Record. Guatemala.

Rhagovelia castanea n. sp.

Antennæ: 42:27:24:22.
Intermediate legs: Male, 100:72:25:34; female, 95:68:25:36.
Posterior legs: Male, 78(24):60:6:12; female, 78(20):70:6:12.

General color dark reddish-brown, almost a black; all appendages dark brown. Body clothed with short brown pubescence; sides of body, legs, and genital segments with longer hairs; legs and segments one and two of antennæ with scattered setæ. Most body sutures black. Pronotum obtusely rounded and with a lighter band in front, wider than long (8:7). Anterior and intermediate acetabula of lighter brown. Venter of same color as dorsum. Posterior tibia armed at apex with short spur; anterior trochanters unarmed.

Apterous Male. Connexivum broad but not reflexed. Body lines straight, tapering posteriorly with no break between last abdominal and first genital segment. First abdominal segment angular at middle. Posterior trochanter armed on posterior surface. Posterior femora greatly incrassated and armed with two apparent rows of spines; the lowermost row with two spines preceded to the base by short teeth; the upper row starting at the apical third and consisting of a series of stout spines. Posterior tibia sinuate and with two rows of teeth, with two teeth near the apex larger.

Apterous Female. Sixth abdominal segment ending with many curved hairs.

Connexivum slightly deeper and more nearly vertical than in the male. Posterior femora moderately incrassated, armed with five larger spines and several small ones, as in the male; teeth on basal third few and small. Posterior tibiæ sinuate and denticulate.

Length, 4.6 mm.; width, 1.4 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous males and females; all from Mera, Ecuador, 1923, F. X. Williams. Types are in the University of Kansas Museum.

R. castanea n. sp. may be close to *R. collaris* (Burm.). This species has the mesonotum covered by the pronotum, and the metanotum emarginate behind. The genitalia is different from other related species.

The specimens included in this species were first thought to be two species, due to a great variation in color and a slight difference in the armature of the posterior femur. Six specimens are dark while twelve were light brown in color. The lighter colored bugs have a larger posterior femur. Comparison of the genitalia of the two forms reveal them to be the same.

Rhagovelia choreutes Hussey.

Rhagovelia choreutes Hussey. Jour. N. Y. Ent. Soc., 33:June, 1925.

Antennæ: "Male, 35:21:19:19; female, 38:22:20:20."
Intermediate legs: "71:53:25:35; 72:56:28:40."
Posterior legs: "54:56:7:14; 57:65:8:16."

The writer's description:

This is a medium-sized, dull black or dark gray species, resembling somewhat *R. obesa* Uhler. Anterior trochanters unarmed. Posterior femur of male moderately incrassated and armed near middle with one long spine and this followed by five or six smaller spines distally. Posterior femur of female about equal in size to the intermediate femur at base. First connexival segment is without a tuft of hairs at apical angle.

"Connexivum (of female) meeting above the last abdominal segment, occasionally above the fourth segment, but not (as in *obesa*) meeting above the fourth segment, then diverging slightly to meet again above the sixth; apex obliquely truncate at an angle of about 45 degrees, forming two short blunt spines about as long as the width of the connexivum, not diverging posteriorly, pilose at their tip. Apex of sixth abdominal segment with a tuft of long curved cilia on each side at the upper lateral angle of the first genital segment, and with several shorter cilia at each side below; the dorsolateral cilia more or less agglutinated, resembling a slender curved spine at either side the genital segment."

Length, 3.8 mm.; width, 1.3 mm.

Notes. In the University of Kansas collection are two groups that belong to *choreutes*. One group of fifty-six specimens was collected in the Arbuckle mountains, Davis, Okla., in 1925 by Dr. R. H. Beamer. These are considered typical of the specimens described by Hussey. The other group of over 110 specimens are from Eddy county, New Mexico, collected by Dr. P. A. Readio in 1927. The specimens are slightly larger and more nearly a black in color, but are probably the same species, or at least a variety of the former. The genitalia are quite similar.

The winged forms have the pronotal process, the females having a long spiniform projection and the males being strongly angular.

Distribution Records. Florida, Oklahoma, and New Mexico.

Rhagovelia collaris (Burm.).

Velia collaris Burmeister. Handb. der. Ent., 2:212, 1835.
Velia fiebrii Guerrin. Sagra's Hist. Cuba, 2:7:174, 1857.
Rhagovelia collaris Mayr. Verh. Zoöl.-bot. Ges. Wien, 15:445, 1865.
R. collaris Mayr, Reise d. Oster. Freg. Nov., Zoöl. Thiel, Zwieter Band, Hemip., p. 180, 1867.
R. collaris Uhler. Proc. Bost. Soc. Nat. Hist., 19:4:434, 1872.
R. collaris Johnson & Fox. Ent. News, 3:60, 1892.
R. collaris Kirkaldy. Ento., 33:72, 1900.
R. collaris Kirkaldy. Ento., 34:308, 1900.
R. collaris Champion. Biol. Centr.-Amer., Heter., 2:134, 1898.

The writer's description based on a specimen from Haiti that was compared with type by Doctor Hungerford:

Antennæ: 28:16:18:14.
Intermediate legs: 60:45:21:25.
Posterior legs: 50:53:6:13.

General color grayish-black with golden pubescence. Transverse flavous band on pronotum conspicuous. Mesonotum hidden. Base of antennæ, base of anterior and posterior femora, edge of connexivum, and all coxæ and trochanters, light brown. Legs and antennæ of a brownish color. Posterior tibia with spur at apex.

Apterous Male. Anterior tibia greatly dilated apically and grooved on inner side. Posterior femur greatly incrassate and armed with two rows of spines, the lower row small and equal throughout, the upper row of about twelve teeth decreasing in size apically. Posterior tibia armed with stout regular spines throughout and slightly sinuate.

Apterous Female. Anterior tibia somewhat dilated. Connexivum vertical and much narrowed in from the base at first, afterwards continuing subparallel. Posterior femur slightly incrassate, armed with four large teeth and four or five minute teeth. Posterior tibia as in the male.

Length, male, 4.7 mm.; female, 5.3 mm.; width, 1.6 mm.

Notes. In his examination of the specimens in the Berlin museum, Doctor Hungerford found four types of *Velia collaris* Burm. They were labeled as follows:

1. Wingless female:
   a. White label with "3406" printed.
   b. Green label with "Port au Pr."; also the word "Ehrenb."
   c. Green label with "*Velia collaris* Br."
   d. White label with "*V. armata* Burm."
2. Wingless female:
   a. White label with "Cat. No. 3406" written.
   b. Green label with "Port au Pr. Ehrenburg."
   c. White label with "*Velia armata* Burm."
3. Wingless male:
   a. White label with "Cat. No. 3406" written.
   b. Green label with "Port au Pr. Ehrenburg."
   c. White label with "*Velia armata* Burm."

Doctor Hungerford says that his specimen 28,293, female, from Port au Prince, Haiti, is the same as No. 1. The male of 28,293 is not like No. 3, however, but the male of 28,306 from Salvador is similar. Therefore the specimens from Haiti (28,293) are called *Rhagovelia collaris* (Burm.), and the other two similar groups are made new varieties of *collaris*.

Doctor Hungerford says the *collaris* specimens in the Vienna Museum determined in 1865 by Mayr are not the same as the Burmeister types in the Berlin Museum.

Distribution Records. San Domingo, Jamaica, and Cuba.

Rhagovelia collaris var. *planipes* n. var.

Antennæ: 30:18:—:—.
Intermediate legs: 62:44:21:21.
Posterior legs: 56:50:6:13.

General color reddish-brown, clothed with brown pubescence. Transverse band on pronotum light brown. Mesonotum covered by pronotum, metanotum slightly emarginate. Posterior tibia armed with short spur at apex.

Apterous Males. Anterior tibia greatly dilated and excavate beneath. Posterior femur enormously incrassate and armed on the basal third with minute spines followed by two rows of stout spines; the upper row of spines of equal size, but larger than the lower row; at the basal third is one large spine just above the first spine in the upper row. Posterior tibia very strongly sinuate and armed with prominent spines, with those on the apical third.

Apterous Female. Anterior tibia slightly dilated and grooved. Connexiva vertical and much narrowed in from the base at first, afterwards continuing subparallel. Posterior femur slightly incrassate, armed at apical two-fifths with a long spine followed by six to ten spines decreasing in size apically. Posterior tibia nearly straight and with prominent small teeth only on the basal half.

Length, 5.6 mm.; width, 1.7 mm.

Notes. This variety is near the *collaris* type No. 3, of which Doctor Hungerford says "*thick* hind femora with all spines but two short, one near the outer end and one near the base. Hind tibia curved and armed with blunt spurs on distal third."

This group of specimens were made a variety of *collaris* because of the similarity of the genitalia and claspers, the proportional measurements, and form. The male differs from type No. 3 in having only one large spine on the posterior femur.

Holotype, apterous male; allotype, apterous female; both from Mt. Cacaguatique Dept., St. Miguel, Salvador, December 14, 1925, collected by R. A. Stirton. Types are in the University of Kansas Museum collection. There are also three specimens from Huigra, Ecuador, collected by F. X. Williams. These include a winged male, an apterous male, and an apterous female.

Rhagovelia collaris var. *pulchra* n. var.

Antennæ: 32:16:17:16.
Intermediate legs: 62:44:21:26.
Posterior legs: 54:50:7:13.

General color brownish-black, with the dorsum of abdomen a reddish-brown, and clothed with golden pubescence. Pronotum broadly rounded behind covering the mesonotum, and with a bright yellow-brown transverse band on the anterior margin. Base of antennæ, base of anterior and posterior femora, all coxæ and trochanters, light brown. Venter, connexiva and most of pleura, light brown.

Apterous Male. Anterior tibia greatly dilated and excavate beneath. Posterior femur greatly incrassate and armed with a long tooth at the basal two-fifths, followed by ten teeth decreasing in size apically, and preceded by a row of minute teeth to the base; also a lower row of small teeth. Denticulations on the posterior trochanters. Posterior tibia armed with stout, small teeth not in a regular row and at apices with a stout spur; not sinuate.

Apterous Female. Anterior tibia slightly dilated and grooved. Connexiva vertical and much narrowed in from the base at first, afterwards continuing subparallel. Posterior femur slightly incrassate and armed with seven teeth. Posterior tibia straight and with no visible denticulations.

Winged Male. Much as in the apterous male. Pronotum produced behind into a slightly elevated spine. Posterior femur not so much incrassate.

Length, male, 5 mm.; female, 5.4 mm.; width, 1.6-1.8 mm.

Holotype, apterous male; allotype, apterous female; morphotype, winged male; paratypes, apterous males and females. All are from Dominica Roseau, B. W. I., January 29, 1926, and collected by P. G. Howes. Types are in the University of Kansas collection and in the British Museum.

Notes. This variety is distinct because of its color markings. Many of the individuals have white eyes, while the normal color is brownish-black.

This variety was placed under *collaris* because of similarity of shape, claspers, genitalia, and proportional measurements. It differs from *collaris* var. *planipes* in color and in armature and incrassate condition of the posterior femur. Also in this variety the anterior tibia of the male is not dilated quite so much.

Among the specimens from the British Museum I find a nearly mature apterous male. It appears to be this variety and is therefore listed. It is from Nat. Forest, Lugohl, P. R., March 10, 1927, by W. A. Hoffman.

Rhagovelia confusa n. sp.

Antennæ: 28:16:18:15.
Intermediate legs: 60:38:24:24.
Posterior legs: 47:44:6:10.

General color grayish-black, clothed with brown pubescence; venter bluish-gray. Pronotum with narrow transverse band of flavous with yellow spots each side of median line. Base of antennæ, the anterior and posterior coxæ and trochanters, brown. Sides of body, legs, and two basal segments of antennæ with long hairs and a few scattered setæ. Head with usual impressed median line crossed with a V-shaped suture on the upper surface. Anterior trochanter unarmed; anterior tibia not dilated. Posterior tibia armed with a short spur at apex. Pronotum in apterous forms sutured off from mesonotum.

Apterous Male. Pronotum wider transversely (6:1), sutured off from mesonotum, which is wider transversely also (4:3); mesonotum nearly covering the median portion of metanotum, both truncate on posterior margin. Connexiva wide near base but tapering posteriorly. Sternal sutures marked by ridges. Venter with slight median carina. Last abdominal segment and first genital segment glabrous beneath; genital segments large. Posterior femur slightly incrassate, armed near middle with one long tooth followed by five to eight short teeth. Posterior tibia very slightly sinuate and often with minute teeth.

Apterous Female. Connexivum semivertical, otherwise as in the male. Last three segments of abdomen with shining spots above. Genital segments small. Posterior femur nearly as in the male.

Winged Forms. Pronotum as broad as long. Elytra extending for some distance beyond the genital segments. Legs as in apterous forms.

Length, winged forms, 4.4-4.7 mm.; apterous female, 3.7-3.9 mm.; apterous males, 3.3-3.4 mm. Width, winged forms, 1.6 mm.; apterous forms, 1.4-1.6 mm.

Holotype, apterous male; allotype, apterous female; morphotypes, winged male and female; paratypes, winged and apterous males and females; all collected in Ecuador in 1925 by F. X. Williams. Localities included are Mera, Tena, Oriente, and Napo, Ecuador. Types are in the University of Kansas collection.

Notes. This species belongs to the *tenuipes* group and differs from that species in having the intermediate tarsal segments equal. It differs from *gregalis* D. & H. by having the apex of the posterior tibia armed with a spur, and from *regalis* D. & H. in size and antennal proportions. Besides the above mentioned, this species differs in many others characters.

Many of the recent writers on the genus *Rhagovelia* have been using proportional measurements as a specific character. The above proportions are averages from a series of twenty-seven specimens as given below. It can readily be seen that the proportions alone are not good characters and are often misleading, especially in a case where only one or two specimens are to be examined.

VARIATIONS IN PROPORTIONAL MEASUREMENTS.

Number	Antennæ				Intermediate leg				Posterior leg				Sex
	I	II	III	IV	Femur	Tibia	TSI	TSII	Femur	Tibia	TI	TII	
1	28	16	17	15	60	37	23	24	46	44	6	12	F
2	28	18	.....	.....	65	40	25	25	51	47	6	11	F
3	28	16	18	15	60	37	24	25	46	45	5	10	Fw
4	28	14	.....	.....	56	35	20	23	44	40	5	10	F
5	28	15	17	15	56	37	23	23	44	43	5	10	Fw
6	28	15	.....	.....	59	36	20	22	46	44	5	10	M
7	32	19	20	17	64	40	26	24	50	47	6	10	M
8	28	14	16	14	55	36	20	22	45	41	5	10	Fw
9	30	16	20	16	.....	.....	.....	.....	50	46	6	10	F
10	28	14	.....	.....	58	36	22	22	46	43	5	10	Mw
11	29	16	.....	.....	60	38	27	22	48	44	6	10	Mw
12	28	18	19	16	64	38	27	24	51	44	6	10	Mw
13	28	17	18	14	62	38	24	24	46	45	6	10	Fw
14	.....	.....	.....	.....	63	40	25	25	48	44	6	10	Mw
15	28	14	17	14	57	36	23	20	45	40	5	10	M
16	29	18	19	16	58	36	22	22	46	42	6	10	M
17	30	18	.....	.....	61	39	24	23	49	44	6	10	M
18	28	16	18	15	63	38	23	24	50	48	.....	.....	F
19	30	18	20	.....	64	40	24	25	48	49	6	10	F
20	.....	.....	.....	.....	64	38	24	25	47	48	6	10	F
21	.....	.....	.....	.....	64	40	24	25	48	48	6	10	F
22	28	18	.....	.....	63	38	24	24	47	44	.....	.....	F
23	28	18	19	16	59	37	24	24	46	44	6	10	M
24	32	18	19	16	63	40	28	24	54	44	5	9	M
25	28	17	19	17	63	39	26	26	51	46	6	10	M
26	28	17	18	.....	58	38	24	23	46	42	6	9	M
27	28	14	.....	.....	56	35	22	21	47	44	5	9	M
Average	28	16	18	15	60	38	24	24	47	44	6	10	.....

Male, M. Female, F. Winged, w.

Rhagovelia crassipes Champ.

Rhagovelia crassipes Champion. Bio. Cent.-Amer., Het., 2:133, 1898.
Rhagovelia crassipes Kirkaldy. Ent., 34:308, 1900.

Antennæ: 33:20:18:17.

The writer's description:

This is a very large, brownish-black species, characterized by the enormously incrassate posterior femora and the bowed hind tibiæ in the male. Pronotum of winged forms produced posteriorly into a long, raised, spiniform process, which is armed beneath at some distance before the tip. Intermediate tarsi with segment II slightly shorter than III. Posterior femur of male "armed with numerous short teeth, the innermost of these arranged in two regular rows, and with one longer tooth towards the base and three or four others towards the apex; posterior tibia bowed inwards to beyond the middle and curved outwards thence to the apex, shortly denticulate on its edge, and armed with one long tooth at about one-third from apex, a shorter one close to it, one near the apex, and another at the apical angle." Posterior femora of female moderately incrassate, armed with one long tooth a little before the middle and with numerous short teeth from middle to the apex. Sixth dorsal segment truncate at apex in male, and rounded at the apex in the female.

Length, 6-7 mm.; width, 2⅕ to 2⅖ mm.

Notes. According to Champion "this species is well characterized by the enormously thickened hind femora and the bowed hind tibiæ in the male sex, both the tibiæ and femora being armed with numerous teeth."

Distribution record: Panama.

Rhagovelia distincta Champion.

Rhagovelia mexicana Signoret. Bull. Soc. Ent. Fr., (5):7:53:55 1877. (Manuscript.)
Rhagovelia distincta Champ. Biol. Cen.-Amer., Het., 2:135, 1898.
Velia distincta Uhler. Walker's Cat. Hemi., 8:161.
Rhagovelia distincta Kirkaldy. Ent., 33:72, 1900.
Rhagovelia distincta Kirkaldy. Ent., 34:308, 1900.
Rhagovelia distincta Van Duzee. Check List of Hemi., 1916.
Rhagovelia distincta Van Duzee. Cat. of Hemi. of Amer. N. Mex., 1917.
Rhagovelia distincta Hungerford. Kan. Uni. Sci. Bul., XI, Dec., 1919.
Rhagovelia distincta Bueno. Ent. News, 32:274, 1921.
Rhagovelia distincta D. & H., Pro. Biol. Soc. Wash., 40:131, 1927.
Rhagovelia excellentis D. & H. Pro. Bio. Soc. Wash., 40:131, 1927.

Antennæ: 32:21:20:18.
Intermediate legs: Male, 72:56:32:32; female, 79:60:32:35.
Posterior leg: Male, 55:57:8:13; female, 57:70:8:14.

"Winged Form. Moderately elongate, black, the legs with a green or bluish-green luster, the pronotum with a narrow transverse flavous mark on each side of the disk in front, the base of the antennæ, the prosternum, the coxæ and trochanters entirely or in part, the base of the anterior femora, the connexival margins, and in the males the terminal ventral segment in the middle and the underside of the first genital segment, more or less flavous; the pleura and under surface bluish-gray; the body, legs and antennæ very finely pubescent, and also clothed (the two apical joints excepted) with long scattered setæ, the pronotum usually with a transverse patch of grayish or silvery pubescence on each side in front. Head with a smooth impressed median line; antennæ moderately long, joint 1 about one-half longer than 2, 2 and 3 equal in length, 4 shorter than 2, stout, fusiform. Pronotum with a

distinct median ridge, and produced behind into a spiniform process, the surface sparsely and finely punctured. Legs long and rather slender, the hind tibiæ with a very short, indistinct tooth at the apex; intermediate tarsi with joints 2 and 3 subequal in length.

"Male: Anterior tibiæ dilated in their apical half; posterior femora moderately incrassate, armed on the inner side with a long, partly flavous tooth at about one-third from the base, and with a row of short teeth extending thence to the apex (in some of the well-developed apterous examples also closely and finely denticulate) and slightly sinuous within. Pronotal spine short. Sixth ventral segment broadly flattened along the middle and feebly arcuate-emarginate at the apex.

"Female: Posterior femora not stouter than the intermediate femora, armed with a very long, acute, blackish tooth at about the middle, and very finely denticulate thence to the apex; posterior tibiæ straight, obsoletely denticulate within. Pronotal spine very long, stout, and raised, armed with a strong tooth at the base beneath.

"Length 5, breadth (of the pronotum) 1½ to 1¾ mm.

"*Apterous Form.* Male and female: Fusiform, the pronotum abbreviated and rounded behind; the abdomen metallic green above, with a stripe of grayish pubescence running down each side of the dorsal surface; the connexivum very broad in the females, extending inwards and overlapping the dorsal surface of the abdomen, the two portions nearly or quite meeting along the median line.

"*Var. Apterous Form.* Male and female: The anterior femora dark to the base; the coxæ and trochanters darker, the latter at most, flavous at the base; the sixth ventral segment broadly flattened, the flattened portion limited on each side anteriorly by a short, angular longitudinal ridge."

Notes. There is a series of specimens in the University of Kansas museum collected by Dr. R. C. Moore in Colorado. These specimens were identified by Bueno as *R. distincta* Champ. several years ago. In 1928 Doctor Hungerford compared these specimens with the type material in the British Museum and says that these specimens are probably *distincta*. In 1927 Drake and Harris described *R. excellentis*, also from Colorado. After a careful examination of three paratypes, from Doctor Drake in the University of Kansas Museum, it was found that the two series of insects are identical. Therefore *R. excellentis* D. & H. is made a synonym of *R. distincta* Champ.

Distribution Records. North America, Mexico, Texas, Indiana, and Colorado.

The varieties of *distincta:* Champion mentions a variety of *distincta*, but does not name it. The writer studied six large series of specimens from the western part of United States. All have a close resemblance to the *distincta* specimens determined by Bueno. Furthermore all seem to fit Champion's original description with exception to the color. After a comparison of the genitalia of the groups it was found that the claspers of the males are similar, but that the structure (pa 1) of the internal genitalia seem constant only for one group. Therefore these series are made varieties of *R. distincta* Champ.

Rhagovelia distincta var. *arizonensis* n. var.

Antennæ: 32:18:17:14.
Intermediate legs: 68:47:23:24.
Posterior legs: 55(13):48:6:12.

General color dark brown, the legs with a metallic green luster; clothed with fine golden-brown pubescence. Pronotum with narrow transverse flavous band, with a brown spot in the middle. Pleura and venter brownish-gray, shading off to dull brown posteriorly. Anterior tibia dilated and excavate within.

Apterous Male. Mesonotum and metanotum truncate, the former partly covered by the pronotum. Abdomen with a shiny spot on each tergite. Posterior femur strongly incrassate, armed at basal two-fifths with a long brown spine, followed by twelve or thirteen shorter stout spines and preceded by a row of minute brown spines. Length, 4.7 mm.; width, 1.3 mm.

Apterous Female. Mesonotum and metanotum slightly emarginate behind. Connexivum strongly reflexed, and nearly meeting over the fourth and fifth segments in some specimens, while nearly vertical in others. Length, 5.4 mm.; width, 1.5 mm.

Winged Forms. Male with pronotum prolonged posteriorly to form an acute angle. Posterior femur slightly incrassate. Female with pronotum prolonged posteriorly into a spiniform process which is armed beneath. Length, 5 mm.; width, 1.8 mm.

Holotype, apterous male, Shinono creek, 1,000 feet above mouth of Grand Canyon (Arizona), September 3, 1925, R. C. Moore; allotype, apterous female, same data; morphotypes, winged male and female, same data; paratypes, many winged and apterous females and males, same data; and also from Enes chasm, Arizona, 500 feet above Colorado river, Shinono quadrangle, September 5, 1923, collected by R. C. Moore.

Notes. This variety is broader than *distincta* Champ., and is brown in color. It is somewhat similar to the variety *harmonia* n. var., also from the Grand Canyon.

Rhagovelia distincta var. *cadyi* n. var.

Antennæ: Male, 29:15:17:15; female, 32:18:18:16.
Intermediate legs: 66:50:26:24; 76:54:25:25.
Posterior legs: 50:51:7:11; 56:61:8:11.

General color black, the legs with a greenish luster; pronotum with narrow transverse, flavous mark on each side of a slight median carina.

Apterous Male. Mesonotum nearly covered by pronotum and truncate behind. Abdomen with a shiny spot on each tergite. Last segment of venter depressed posteriorly and with a distinct ridge on either side. Posterior femur moderately incrassate, armed at the basal two-fifths with a long, bent black spine which is followed by ten shorter stout spines and preceded by a row of short black teeth. Length, 4.8 mm.; width, 1.4 mm.

Apterous Female. Mesonotum and metanotum slightly emarginate posteriorly. Apices of first, fourth and fifth segments of the connexiva with tufts of fine hairs. Posterior femur slightly incrassate, armed at near the middle with a long spine followed by five or six small spines. Length, 5.2 mm.; width, 1.5 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous males and females; all from North Platte, Wyo., September 2, 1926, collected by Geo. Cady. All types in the University of Kansas collection.

The male of this variety is much like *distincta;* the connexiva of the female is not so much reflexed and is semivertical.

Rhagovelia distincta var. *harmonia* n. var.

Antennæ: 29:18:16:14.
Intermediate legs: 62:44:25:26.
Posterior legs: 50(16):56:6:12.

General color dark brown, with all appendages of a reddish-brown color. Anterior tibia somewhat dilated.

Apterous Male. Much as in var. *arizonensis* n. var., but the posterior femur is slightly more incrassate. Length, 4.7 mm.; width, 1.3 mm.

Apterous Female. Connexivum much reflexed and nearly meeting over the third segment. Abdomen narrower than in *arizonensis.* Length, 5.3 mm.; width, 1.5 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous males and females; all from Grand Canyon, Arizona, August 11, 1927, by P. A. Readio; also specimens from Yavapai county, Arizona, August 9, 1927, by L. D. Anderson.

Rhagovelia distincta var. *modesta* n. var.

Antennæ: 24:15:15:14.
Intermediate legs: 56:38:20:23.
Posterior legs: 46:42:6:10.

General color grayish-black, the legs with a brownish luster. Base of antennæ, edge of acetabula, anterior and posterior coxæ, trochanters, base of anterior and posterior femur, edge of connexiva, and under sides of genital segments, light brown. Anterior tibia dilated apically.

Apterous Male. Pronotum broader than long, covering most of mesonotum; metanotum truncate. Last segment of venter depressed posteriorly and with a distinct carina each side. Posterior femur moderately incrassate, armed at basal two-fifths with a long brown spine, which is followed by ten to twelve shorter stout spines and preceded by a row of minute black spines. Length, 4.6 mm.; width, 1.3 mm.

Apterous Female. Connexiva strongly reflexed but not meeting, and running subparallel over the abdomen; hairs on apices of first segment slightly longer. Supra-anal plate with lateral tufts of stiff brown hair. Intermediate femur somewhat flattened near the middle. Posterior femur more incrassate than intermediate, slightly swollen at the middle and armed with a long spine at apical two-fifths and five or six shorter ones to the apex. Length, 4.8 mm.; width, 1.4 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous males and females; all from San Antonio, Mexico, July 17, 1927, by R. H. Beamer. All types are in the University of Kansas Museum.

Notes. This variety is somewhat like *distincta* and is very similar to variety *valentina* n. var. *Valentina* differs from this variety in the female having a longer and narrower abdomen, and the posterior femur armed with two large and five small teeth, and in the male having the posterior femur more incrassate.

Rhagovelia distincta var. *proxima* n. var.

Antennæ: 29:16:17:16; female, 32:18:18:16.
Posterior legs: 60:48:25:24; female, 66:49:25:24.
Posterior legs: 50(16):49:8:12; female, 55:63:8:12.

General color black, the legs with a greenish luster; pronotum with narrow transverse, flavous mark on each side of a slight median carina.

Apterous Male. Mesonotum covered by pronotum; metanotum truncate behind. Abdomen with a shiny spot on each tergite. Last segment of venter depressed posteriorly and with a distinct ridge on either side. Posterior femur moderately incrassate, armed at the basal two-fifths with a long, bent, black spine, which is followed by ten to twelve shorter stout spines and preceded by a row of short black teeth. Length, 4.8 mm.; width, 1.4 mm.

Apterous Female. Mesonotum and metanotum slightly emarginate posteriorly. Apices of first, fourth and fifth segments of the connexiva with tufts of fine hair; genital segments also with some fine hair. Connexiva strongly reflexed. Posterior femur slightly incrassate, armed near the middle with a long spine followed by seven or eight small spines. Length, 4.8 mm.; width, 1.4 mm.

Winged Forms. Much as in apterous forms. Posterior femur of male not so much incrassated. Pronotum of male with a slight backward projecting point; female with a backward projecting spine, armed beneath. Length, 5 mm.; width, 1.5 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous and winged males and females; morphotypes, winged male and female; all from Boulder creek, Colorado, 1925, by Beamer and Lawson.

Notes. This variety is very near *distincta,* differing in size. It is also near variety *cadyi,* from which it differs by the male being more robust and the female with the connexiva more reflexed.

Rhagovelia distincta var. *valentina* n. var.

Antennæ: 30:16:16:14.
Intermediate legs: 64:41:20:24.
Posterior legs: 53:49:8:11.

General color black, the legs with a greenish luster; pronotum with narrow transverse fulvous mark and yellow spot on each side of a slight median carina. Base of antennæ, prosternum, the trochanters and coxæ entirely or in part, the base of the anterior femur, edge of the first genital segment, and edge of connexivum, yellowish-brown. Clothed with fine gray pubescence. Anterior tibia dilated and hollowed on inner side.

Apterous Male. Mesonotum and part of metanotum covered by pronotum. Last segment of venter depressed posteriorly and with a distinct ridge each side. Posterior femur strongly incrassate, armed at the basal two-fifths with a long, bent, brown spine which is followed by eight or nine shorter stout spines, and preceded by a few minute black spines. Length, 4.5 mm.; width, 1.4 mm.

Apterous Female. Mesonotum and metanotum slightly emarginate behind. Connexivum strongly reflexed and nearly meeting over the fourth and fifth segments; with slightly longer hairs on the apices of first segment. The last

abdominal segment and first genital segment with more hairs, the latter usually with a group of long, stiff, black hairs extending laterally. Last segment of venter darker, and broadly rounded. First genital segment beneath brownish and with a distinct carina. Posterior femur more incrassate than the intermediate, slightly swollen within, and armed at the apical two-fifths with a long, curved, brownish spine, followed by five or six short, stout, black spines. Length, 4.8 mm.; width, 1.5 mm.

Winged Form (Cochise county, Arizona). Much as in apterous forms. Pronotum produced posteriorly in the male into an acute process; in the female produced into a long spiniform process, which is armed at base beneath. Length, 5 mm.; width, 1.6 mm.

Holotype, apterous male, Valentine, Tex., July 23, 1927, R. H. Beamer; allotype apterous female, same data; paratypes, apterous males and females, same data. Also examined winged specimens from Presidio county, Texas, and Cochise county, Arizona, all collected by R. H. Beamer in 1927. All types are in the University of Kansas collection.

This variety is near variety *modesta* n. var. See notes under that form.

Rhagovelia elegans Uhler.

Rhagovelia elegans Uhler. Proc. Zoöl. Soc. Lond., 1894, p. 216.
Rhagovelia elegans Champion, Biol. Cent.-Am., Het., 2:135, 1898.
Rhagovelia elegans Kirkaldy. Ent., 34:309, 1900.

Antennæ: 28:21:17:14.

This is a reddish-brown species belonging to the group characterized by having the posterior tibia armed with a curved hook. Pronotum fuscous. Posterior femora slightly thickened and armed with about seven long teeth, the two inner ones being longer and thicker. Venter yellow but sometimes dusky and polished. The border of connexivum is brighter yellow, as are the genital segments. Length, 4½-5 mm.; width, 1¾-2 mm.

Notes. Champion says that this species has the tibiæ armed with a long, slender hook at the apex in both sexes as in his *R. insularis* and *uncinata*. He says that this species is distinguished from *R. insularis* by its more elongate form, longer legs, and color of pronotum—these characters are good if both specimens are at hand.

Distribution Records. Grenada.

Rhagovelia femoralis Champion.

Rhagovelia femoralis Champ. Biol. Cent.-Am., Het., 2:138, 1898.
Rhagovelia femorata Kirkaldy. Ent., 34:308, 1900.
Rhagovelia femoralis Bergroth. Psyche, 21:74, 1914.
Rhagovelia femoralis D. & H. Proc. Biol. Soc. Wash., 40:131, 1927.

Antennæ: 29:15:15:15.

The writer's description:

This is a common black species of moderate size. The antennæ are comparatively short, the middle pair of legs very long, and the posterior pair short. The posterior tibia of male is almost straight, denticulate within and armed with a long tooth at some distance from the apex. Posterior femur is enormously incrassated, armed with two rows of rather long teeth extending from about the basal third to near the apex; one tooth at basal third much

longer. Intermediate tarsus has segment II slightly shorter than III. Length, 4⅓ mm.; width, 1½ mm.

Notes. Of this species Champion says, "Allied to *R. crassipes*, but much smaller, with relatively shorter hind legs, the armature of both femora and tibiæ very different, the antennæ shorter, the intermediate tibiæ relatively shorter, the metasternum without tubercle in the male, etc. *R. collaris* from the Antilles and South America, one of the types of which is before me, is very like the present species, but it has the anterior tibiæ strongly dilated and the hind tibiæ sinuous (as in *R. crassipes*) in the male, the connexival margins pale, etc."

Distribution Records. Panama.

Rhagovelia festae Kirkaldy.

Rhagovelia festæ Kirkaldy. Bol. Mus. Zoöl. Anat. Comp. Torino, 14:350:4, 1899.
Rhagovelia festæ Kirkaldy. Ento., 34:308, 1900.

Antennæ: 30:20:15:20.

The writer's description:

This is a small grayish species belonging to the group characterized by the sutured-off pronotum. Antennal segment III is shorter than either II or IV. The anterior femora is a little shorter than the tibiæ, and is about four times as long as the tarsi. The posterior femora (of female) are normal in size and unarmed, as are also the tibiæ. Length, 2.6 mm.

Distribution Records. Ecuador.

Rhagovelia flavicincta Bueno.

Rhagovelia flavicincta Bueno. Trans. Amer. Ent. Soc., 50:243-252, 1924.

Antennæ: Male, 24:11:13:13 and 24:14:15:14; female, 24:14:15:14.
Intermediate legs: Male, 49:35:17:21; female, 50:36:17:22.
Posterior legs: Male, 40:36:4:8; female, 39:37:4:9.

"*Males, Apterous.* Femoral spine long, curved, black-tipped, three-fifths its length from apex, followed apically by five or six smaller ones of nearly equal length; hind femora incrassate, nearly twice as thick as intermediate; posterior tibiæ with a straight spur at apex; anterior trochanters with a stout black spine.

"*Females, Apterous.* Pronotum truncate; posterior femora slightly enlarged; femoral spine slender, curved, followed by about five minute spines which grow smaller toward the apex; spine placed two-fifths of its length from tibial joint. No spine on anterior trochanters. Connexiva not quite meeting over last abdominal segment; last connexival angle produced into a stout black spine; first segment of connexivum fringed with closely appressed long black hairs, which have the appearance of a long black spine; connexivum broadly margined with flavous, glabrous."

Length, males, 3.2-3.5 mm.; females, 3.5-3.8 mm.; width, male, 1.1 mm.; female, 1.2 mm.

Type locality is Raleigh, North Carolina. The writer collected this species commonly in Brunswick County, Virginia, and Northampton County, North Carolina. One winged form was taken.

Comparative Notes. This species is very close to *R. obesa* Uhler. The writer examined a male paratype of *flavicincta* and also collected several hundred specimens of this species in both Virginia and North Carolina. The

female of *flavicincta* differs from *obesa* by the more prominent flavous markings, by the larger yellow spots on the pronotum, and by the armature of the posterior femur that consists of one long and four or five distinct shorter spines. The males of this species may be distinguished from *obesa* by a short, distinct, black spine on the outer aspect of the anterior trochanter.

The winged specimen collected in Virginia is similar to *R. obesa*. The tip of the pronotum is produced and curved upward, with the extreme end expanded and very faintly emarginated. The flavous markings are more distinct on this species. The abdomen is not compressed as in the wingless female.

Rhagovelia gigantea Gould.

Rhagovelia gigantea Gould. Trans. Ent. Soc. Am., 21:417, 1928.

"Antennæ: 42:35:24:18.
"Intermediate legs: 74:76:19:22.
"Posterior legs: 74(wide 22):74:17:18.

"*Apterous Male.* General color light brown, covered with short brown pubescence; legs, sides of body, and two basal segments of the antennæ with longer hairs and a few scattered setæ. Head with medium impressed line, crossed by two inverted V's, the posterior one at the posterior margin of the head. Connexiva nearly vertical and about three-fourths the width of dorsum, extending beyond the last abdominal segment to form a long, stout projection equaling in length the genital segments. Venter covered with long hairs of the same color as on the dorsum; venter with a faint carina that terminates in a small round projection on the last abdominal segment.

"Pronotum longer than wide (10:9), rounded behind and covering most of the mesonotum; anterior margin with silvery iridescent band interrupted by the median carina and broadening at the humeral angles. Small yellow scalelike pads project from under the pronotum in the normal position of wings (length 0.8 mm., width 0.2 mm.). The hind margin of the metanotum, the first abdominal segment except the median line, and lateral margins of the second abdominal segment, silvery iridescent.

"Posterior femur greatly incrassate but abruptly narrowed in the apical third, this being marked by a short, stout curved tooth; from this tooth to the base are five stout teeth, diminishing in size toward the base. Numerous minute teeth scattered on femur below larger teeth. Posterior tibia armed with rounded teeth of irregular size, usually consisting of two small teeth between two large ones; at the base of the tibia are several larger teeth; the apex armed with a very minute tooth.

"Genital segments hairy. Claspers long, meeting some distance above the body. Length, 8.4 mm.; width, 2.2 mm."

This species was originally described from one specimen, an apterous male loaned by the U. S. National Museum. In 1928 Doctor Hungerford found eleven unnamed specimens of this species in the Budapest Museum, and through the kindness of Doctor Horvath was able to forward the specimens to the writer. Upon examination the characters of the holotype were found not to be constant in the Budapest Museum specimens. Therefore the following descriptions are added to include the characters of all forms:

Formulæ for all forms:

Antennæ: 28:23:16:14.
Intermediate legs: 47:47:12:14.
Posterior legs: 45:49:11:12.

Apterous Male. The males from the Budapest Museum show that the character of the enormously incrassated posterior femur is not constant, for

three of the six specimens have femora only proportionally larger than the intermediate femora. One character not noted in the original description is the presence of three horns on the supra-anal plate. The tips of the lateral horns are diverging, while the central horn projects backward.

Apterous Female. General color light brown, covered with short, brown pubescence. The connexiva meeting over the last two abdominal segments and projecting out over the first genital segment. Silvery iridescent markings much as in the male, but not so bright. Small scalelike pads appear to be rudimentary wings. The posterior femur not much thicker than the intermediate femur at its widest part; armed with three equally spaced teeth near the middle; several series of minute teeth are also present. Posterior tibia armed with barely visible teeth. Genital segments small, the second somewhat telescoped into the first. On its dorsolateral margin the first genital segment has projections posteriorly, protecting the second. On the ventral surface of the first genital segment a faint carina. Length, 8 mm.; width, 2.1 mm.

Winged Forms. General color much as in the apterous forms. The silvery iridescent markings brighter. Pronotum profusely punctate, such markings extending only into the posterior distal angles of the iridescent area. Pronotum produced posteriorly into an angle, the tip of which is turned slightly upward. Elytra a dark brownish-black, almost black. Veins distinct but not prominent; basal fourth of each elytron and a spot in the closed R (?) cell silvery. Posterior femur of both sexes moderately incrassate, with two large teeth at about the apical third and three smaller teeth below. Trochanter armed with minute teeth. Tibia with several rows of teeth on its posterior surface, the middle row being slightly larger and the teeth increasing in size proximally. Length, 8.4 mm.; width, 2.8 mm.

Holotype, apterous male, from Cincinnati, Colombia, in the U. S. National Museum; allotype and two parallotypes, apterous females from Sierra S. Lorenzo, Colombia; morphotypes, winged male and female; paramorphotype, winged male and female; metatype, four apterous males; all collected with the allotype. Allotype and morphotypes in the Hungarian National Museum. Examples also in the University of Kansas collection.

Notes. The scalelike pads are found on all apterous forms and resemble rudimentary wings. They come out from under the metathorax as a true appendage, and are smooth, yellow and waxlike in appearance.

Rhagovelia gregalis Drake & Harris.

Rhagovelia gregalis D. & H. Proc. Biol. Soc. Wash., 40:131, 1927.

Antennæ: "38:23:23:20."
Intermediate legs: Male, "74:48:32:28"; female, "68:46:30:29."
Posterior legs: Male, "55:60:7:10"; female, "54:60:8:11."

The writer's description:

This is a small brownish-black species belonging to the group characterized by the sutured-off pronotum. Posterior margin of pronotum is broadly emarginate; mesonotum is broader than long and truncate behind. Anterior trochanters are unarmed. Posterior femora are armed with one long spine just behind the middle, followed by six to nine shorter spines. Posterior tibiæ are

without a distinct spur at apex. The connexivum of the female is very wide and has the outer edge rounded. Winged forms do not have the pronotum produced posteriorly.

Length, male, 3.06 mm.; female, 3.5 mm.; winged forms, 3.95 mm.; width, male, 1.27 mm.; female, 1.4 mm.; winged forms, 1.54 mm.

Distribution Record. Honduras.

Rhagovelia hirtipes Drake & Harris.

Rhagovelia hirtipes D. & H. Proc. Bio. Soc. Wash., 40:131, 1927.

Antennæ: "30:16:—:—."
Intermediate legs: "61:50:30:28."
Posterior legs: "45:58:8:11."

This species is known only from a winged female, but presumably it is close to *R. gregalis* D. & H. General color is blackish, with the appendages a brownish-black. The pronotum is triangularly produced posteriorly with its apex subtruncate and clothed with long hair. Posterior femora are "clothed within with numerous long yellowish-brown hairs, armed with a long, curved, brown spine at the basal two-thirds, which is preceded by a row of short, stout teeth and followed by four to five very short spines." Length, 4.28 mm.; width, 1.52 mm.

Notes. This species is presumably close to *R. gregalis* D. & H., but certain important characters are as yet unknown and therefore this species has to be left out of the key. Drake and Harris say that "the patch of long hairs at the apex of the pronotum and the short hind femora with their hairy clothing distinguish this species from *R. gregalis.*"

Distribution Record. Honduras.

Rhagovelia insularis Champion.

Rhagovelia insularis Champ. Biol. Cent.-Am., Het., 2:135, 1898.
Rhagovelia insularis Kirkaldy. Ent., 34:308, 1900.

Antennæ: 32:22:19:17; winged, 33:24:20:18.
Intermediate legs: 70:50:19:29; winged, 74:56:20:30.
Posterior legs: 64:56:5:12; winged, 68:64:5:12.

This is a moderate-sized, reddish-brown species belonging to the group characterized by a curved hook at the apex of the posterior tibia. The pronotum is rufo-castaneous. Posterior femora armed with five or six long teeth, the first, second and fourth longest, the first and second being a little more distant than the others. Length, 4-4¾ mm.; width of winged forms, 1½-1⅔ mm.; apterous forms, 1⅓ mm.

Notes. In the University of Kansas collections there are specimens from Brazil and the Island of Trinidad. The proportional characters of the legs and antennæ vary much in the different individuals. The color is also a variable character in many instances.

Specimens from Panama, Trinidad and Brazil were compared by Doctor Hungerford with *R. insularis* Champ. types in the British Museum. Doctor Hungerford believes the specimen from Panama to be *insularis* and probably the other specimens, also, although he says they are darker.

The Panama specimen (No. 1) is a winged male measuring 5.6 mm. in length, 1.9 mm. in width, and has the spines on the posterior femur as in the

type specimen, *i. e.*, 1st, 2d and 4th of equal size and longer than 3. The wingless male (No. 2) from Trinidad is 4.7 mm. in length, 1.3 mm. in width, and the armature of the posterior femur is as in No. 1. A winged male from Brazil (No. 3) is 5.1 mm. in length, 1.7 mm. in width, and has spines 1 and 2 equal and longest, spines 3 and 4 equal and somewhat shorter, and spines 5 and 6 equal and quite small. A wingless female from Brazil (No. 4) has spines 1 and 2 longest with 2 slightly longer than 1, 3 and 4 equal, and spines 5 and 6 equal and small. The measurements of No. 4 are the same as No. 2. All other specimens from Brazil have the arrangement of the spines as in No. 3.

It can be seen from the above that there is a wide variation in armature and, as previously remarked, a variation in color. However, the claspers and genitalia of specimens are the same in every detail and therefore these thirteen specimens are called one species—*R. insularis* Champ., based on comparisons by Doctor Hungerford.

Distribution Records. Trinidad, Panama, Brazil, Colombia.

Rhagovelia knighti Drake & Harris.

Rhagovelia knighti D. & H. Proc. Biol. Soc. Wash., 40:131, 1927.

Antennæ: "26:16:18:15."
Intermediate legs: "56:41:21:26."
Posterior legs: "Male, 42:39:6:11; female, 41:45:5:10."

This is a small, blackish species, closely related to *R. obesa* Uhler. The anterior trochanters of the male armed with a dark spine; posterior femur is rather strongly incrassated, armed with a row of short teeth on the basal two-fifths and from there to apex with a row of eight or nine longer spines that decrease in size distally, and also a row of smaller teeth. Pronotum of female is broadly rounded on its posterior margin; connexivum has a tuft of brown hairs at apex and is faintly produced. The posterior femora of the female is armed with a longer spine at the apical two-fifths, and from there to apex with three or four very short spines. Length, 3.2 mm.; width, 1.2 mm.

Notes. This species is very similar in form, size, general color, and markings to *R. obesa* Uhler. The males of the two species are so similar that Drake and Harris could give no good character by which to separate them. They say the female is easily recognized by the rounded posterior margins of the pronotum and by having the apical angle of the connexiva only slightly produced. Whether this species should be grouped in the key with *obesa* cannot be determined until a winged specimen has been identified. An examination of the genitalia of the two species might prove them to be the same.

Distribution Record. Missouri.

Rhagovelia longipes n. sp.

Antennæ: Male, 24:12:16:17; female, 24:11:16:15.
Intermediate legs: 67:41:27:20; 64:40:24:21.
Posterior legs: 40:64:3:6; 40:58:3:6.

General color grayish-black, clothed with brown pubescence and a few long hairs on the sides of the body, legs, and the two basal segments of the antennæ. Base of first antennal segment brown; venter bluish-black, except the median portion of the last abdominal segment, which is shining black. Pronotum with

a slight median carina and rounded posteriorly. Elytra brown. Posterior tibia unarmed at apex.

Winged Male. Body compressed vertically. Posterior femur not so large as base of the intermediate femur, and unarmed. Intermediate leg and posterior tibia very long.

Winged Female. Body compressed as in the male. Posterior femora unarmed and not incrassated.

Length of body (tips of wings broken), 3.75 mm.; width, 1.56 mm.

Holotype, winged male; allotype, winged female; paratype, winged male; all from Tena, Ecuador, near Oriente, March 29, 1923, collected by F. X. Williams. Types are in the University of Kansas collection.

Comparative Notes. This species is very close to the other new species from Ecuador that are characterized by the small pronotum which is sutured off from the mesonotum. Even though only the winged forms of this species are known, it probably goes in the *tenuipes-festæ* group. In addition to the pronotal character, this species is distinguished from all other related species by its proportional measurements, by its long posterior tibiæ, by its long intermediate legs, and by the unarmed posterior femora.

Rhagovelia lucida n. sp.

Antennæ: 24:12:15:13.
Intermediate legs: 52:41:21:23.
Posterior legs: 38:40:4:10.

Color a brownish-black, covered with golden brown pubescence. Pronotal band indistinct, but with a yellow spot each side of center. Pronotum short (9:16) and obtusely rounded behind; mesonotum broadly rounded and broader than long (16:5); metanotum nearly covered. Antennal segment one curved and thickened apically; segment three widened and club-shaped. Connexivum not reflexed and of the same color throughout. Base of antennæ, base of anterior and posterior femora (slight), all coxæ, and the anterior and posterior trochanters, reddish-brown. Venter of slightly darker color. Anterior trochanter unarmed; posterior tibia with a short spur at apex.

Apterous Male. Genital segments large. Posterior femora slightly incrassated and armed at middle with a moderately long spine, followed by about five spines apically and a row of distinct spines basally.

Length, 3.9 mm.; width, 1.2 mm.

Type, apterous male; Theresopolis, Rio de Janeiro, Brazil, September 8, 1923, G. L. R. Hancock. Type is in the British Museum.

This species is somewhat like *R. trista* n. sp. in the structure of the pronotum but differs in the male claspers, the proportional measurements and the armature of the posterior femora.

Rhagovelia obesa Uhler.

Rhagovelia obesa Uhler. Proc. Bost. Soc. Nat. Hist., 19:4:434, 1872.
Rhagovelia obesa Uhler. Kingsley Nat. Hist., 2:249-276, 1884.
Rhagovelia obesa Uhler. Ck. List, Hemi., Brooklyn Ent. Soc., 1886.
Rhagovelia obesa Uhler. Proc. Zoöl. Soc. Lond., p. 215, 1894.
Rhagovelia obesa Champ. Biol. Cent.-Am., Het., 2:135, 1898.
Rhagovelia obsea Kirkaldy. Ent., 34:308, 1900.

Rhagovelia obesa Bueno. Can. Ent., 39:2:61-64, 1907.
Rhagovelia obesa Van Duzee. Ck. List Hemi., N. Y. Ent. Soc., 1916.
Rhagovelia obesa Van Duzee. Cat. Hemi. N. A., 1917.
Rhagovelia obesa Hungerford. Kan. Uni. Sci. Bul., XI, Dec., 1919.
Rhagovelia obesa Parshley. S. Dak. St. Col. Tech. Bul. 2, 1922.
Rhagovelia obesa Bueno. *In* Hemi. Conn. Geo. & Nat. Hist. Survey, Bul. 34, p. 418, 1923.
Rhagovelia obesa Bueno. Trans. Am. Ent. Soc., 50:250, 1925.
Rhogovelia obesa Hussey. Jour. N. Y. Ent. Soc., 33:June, 1925.
Rhagovelia obesa Bueno. Cornell Uni., Memoir 101, 1926.
Rhagovelia obesa Drake & Harris. Proc. Bio. Soc. Wash., 40:131, 1927.

"Allied to *R. collaris* Mayr (Burm.), but differs in the colors, in the more contracted abdomen, with its acutely produced posterior tips of the connexivum, and in the absence of dense long hairs at the tip of venter in the same sex.

"Brownish, or bronze-black; the underside bluish, sericeous; when very mature less polished, but more densely powdered with bluish, or cinerous bloom. Head black, velvety, the front almost truncated, cinerous, with an impressed longitudinal line running almost to the base, a few long hairs about the sides and above; the cranium a little elevated on the middle, extending back in the form of a triangle; the base of the occiput transversely a little carinately elevated. Labrum and lateral lobes yellowish, or rufo-piceous; rostrum black, reaching to the tips of the anterior coxæ. Eyes round, brown. Antennæ black, excepting the base of the basal joint, less hairy than in *R. collaris;* the basal joint stoutest, curved, about twice as long as the second joint, the second subequal to the third, the fourth decidedly shorter than the third. Thorax obese, the pronotum velvety blackish, sparingly clothed about the sides with fine golden pubescence; collum with an orange band which is interrupted in the middle; middle line faintly carinated; the tip of pronotum produced at tip, curved upwards, its extreme end expanded, emarginated, and each process granulated; the humeri prominent in the winged individuals, in the unwinged it is obliquely rounded. Pectus bluish, sericeous, each side of prosternum broadly orange. Coxæ, trochanters, and usually the base of femora yellow; the femora bronzed a bluish-black, minutely hoary pubescent; the tibiæ and tarsi duller black; posterior femora of the males stouter than of the females, in both with a yellow, black-tipped, curved spur beyond the middle and from it to near the tip series of minute teeth. Abdomen moderately compressed (very strongly compressed in unwinged females), minutely sericeous, pubescent, excepting on the middle of tergum, which is bald, shining black; the raised upper edge of the connexivum orange, in the female the posterior tips produced into long slender spines. The middle of the antegenital ventral segment of the male quadrately, broadly flattened, each side of which a little elevated. Basal genital segment of the female broadly black on the middle. The cerci of the male are long, slender curved hairy processes.

"Length, 3½ to 4 mm.; breadth of pronotum, 1¾ mm."

Notes. This is a very common species of wide distribution and is related to, or identical with, several recently described species, including *knighti* D. & H., *flavicincta* Bueno, and *arctoa* Bueno. However, the genitalia of the last two named have been examined and there appear to be slight differences.

Distribution Records. Ontario, Maine, Massachusetts, Vermont, New York, New Jersey, Pennsylvania, Maryland, District of Columbia, Virginia, North Carolina, Florida, South Carolina, Ohio, Michigan, Tennessee, Utah, California, Colorado, and Illinois.

Rhagovelia obscura n. sp.

Antennæ: 27:16:19:15.
Intermediate legs: 58:38:23:23.
Posterior legs: 48:43:6:10.

General color grayish-black, clothed with brown pubescence and with long hairs on the sides of body, legs, and two basal segments of antennæ. Dorsum of abdomen and edge of connexiva glabrous and brown. Venter bluish-gray, except the median portion of last abdominal and the genital segments. Pronotum sutured off from mesonotum and with a dark brown spot anteriorly. Mesonotum and metanotum cut off squarely on posterior margin. Long hairs on acetabula of posterior legs resembling a spine. Posterior tibia armed with straight spur. Anterior tibia with a slight groove near apex.

Apterous Male. Abdomen gradually tapering. Genital segments large. Posterior femur slightly incrassate, straight on anterior margin, and armed with one long, curved spine at about the center, followed by about eight short teeth. Posterior tibia with serrate teeth of equal size throughout.

Apterous Female. Abdomen broad as in the male. Posterior femur slightly incrassate, armed with one long and five short teeth. Genital segments small.

Length, 3.5-3.75 mm.; width, 1.2-1.4 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous males and females; all collected by F. X. Williams at Naranjapata, Ecuador, December 14, 1923. Types are in the collection of the University of Kansas.

Notes. This species is near *R. confusa* n. sp., but differing from it in the armature of the posterior tibia, the anterior tibia with a groove, and the genitalia. The proportional measurements of the specimens included in this species varied, but the numbers used are the averages.

Rhagovelia oriander Parshley.

Rhagovelia oriander Parsh. S. Dak. St. Col. Tech. Bul. 2, p. 19, 1922.
Rhagovelia oriander Bueno. *In* Conn. Geo. & Nat. Hist. Survey, Bul. 34, p. 418, 1923.
Rhagovelia oriander D. & H. Proc. Bio. Soc. Wash., 40:131, 1927.
Rhagovelia oriander Bueno. Trans. Am. Ent. Soc., 50:250, 1925.

Antennæ: 30:20:20:18.
Intermediate legs: 56:44:24:30.
Posterior legs: 48:46:5:11.

This is a moderate-sized, dark brown species that is characterized by the pronotum being produced in the apterous forms. Parshley gives the proportion of the antennal segments as 18:10:10:9 and also says that the second and third segments of the middle tarsi are equal in length. In the male the pronotum is moderately developed, and extending angulately back over the metanotum; while in the female the pronotum is greatly developed and continued posteriorly in a knobbed and elevated process. The posterior femora of the male is strongly incrassate, being armed at the middle with a long curved spine followed by eight smaller spines; also there is a row of small teeth just below this row and extending the full length of the femur. The posterior femora of the female is but slightly thickened and armed with one long and about seven short spines. The posterior tibia of the male is serrately denticulate within, while the tibia of the female is unarmed. Body of the female strongly compressed; connexivum strongly reflexed against body

and scarcely, if at all, meeting over the last abdominal segment. In the winged forms the pronotum is much as in the apterous forms.

Length, 3.4-3.9 mm.; width, 1.1-1.6 mm.

Distribution Records. South Dakota, Ohio, Iowa, Minnesota, and Kansas.

Rhagovelia plumbea Uhler.

Rhagovelia plumbea Uhler. Proc. Zoöl. Soc. Lond., p. 217, 1894.
Rhagovelia plumbea Kirkaldy. Ent., 34:308, 1900.
Trochopus marinus Carpenter. Ent. Mo. Mag., 24:78, 1898.
Rhagovelia plumbea Hungerford. Kan. Uni. Sci. Bul., XI, Dec., 1919.
Rhagovelia plumbea Bueno. *In* Conn. Geo. & Nat. Hist. Survey, Bul. 34, p. 418, 1923.
Rhagovelia plumbea D. & H. Proc. Biol. Soc. Wash., 40:131, 1927.

Antennæ: 30:19:23:18.

This is a small bluish-black species belonging to the group characterized by the sutured-off pronotum. The posterior femur is unarmed. Length, male, 2½ mm.; female, 3¼ mm.; width, male, 1 mm.; female, 1¼ mm.

Notes. In 1898 Carpenter described *Trochopus marinus* and in 1900 Kirkaldy put it in synonymy with *R. plumbea.* The original descriptions do not agree in many of the essential characters. For instance, Carpenter said the posteria femora were armed with three spines, while Uhler gave the posterior femora as unarmed. Antennal proportions are also different.

This is one of the species that lives on the salt water of bays.

Distribution Records. Florida, Grenada, St. Vincent, and Jamaica.

Rhagovelia regalis Drake & Harris.

Rhagovelia regalis D. & H. Proc. Bio. Soc. Wash., 40:131, 1927.

Antennæ: "34:20:20:15."
Intermediate legs: "65:44:26:26."
Posterior legs: "51:51:4:7."

This is a moderately small, black species, belonging to the group characterized by a very short pronotum. The posterior femora are slightly incrassate and about normal in the female, armed with a long spine at the middle and followed apically by seven to ten shorter spines. Hind tibia of male has a slender spur at apex. Connexivum of the female is broad, abruptly rounded and clothed at apex with longer hairs.

Length, 2.6-3 mm.; width, 1.2-1.4 mm.

Notes. Of this species Drake & Harris say, "The short pronotum, the formulæ of the antennæ and legs, and the shape of the connexivum distinguish *regalis* from related species."

Distribution Record. Honduras.

Rhagovelia relicta n. sp.

Antennæ: 22:14:—:—.
Intermediate legs: 50:34:13:22.
Posterior legs: 39:36:4:12.

General color brownish-black, clothed with golden pubescence. Genital segments, antennæ and legs with longer hairs and a few scattered setæ. Pronotum with bright yellow-brown transverse band; broader than long (15:13) and broadly rounded behind. Mesonotum completely hidden; metanotum small. Base of antennæ, base of anterior and posterior femora, all coxæ, an-

terior and posterior trochanters, pronotal band and edge of connexivum, light brown. Venter nearly black and with a slight median carina. Anterior trochanters unarmed; posterior tibia with long stout spur at apex.

Apterous Male. Connexivum broad and not reflexed. Posterior femora strongly incrassate and armed with two irregular rows of long teeth varying in size, the first two on the upper row being the longest. Posterior tibia slightly sinuate and armed at apical one-fifth by a long spine, preceded by a single row of stout teeth to base, and followed by two or three small teeth; apex armed with a stout spur.

Apterous Female. Connexivum semivertical. Posterior femur slightly incrassate and armed with one long tooth near the middle and eight to ten apically. Posterior tibia straight and without prominent tooth.

Length, 3.7-4 mm.; width, 1.3 mm.

Holotype, apterous male; allotype, apterous female; both are from Campinas, Estado do Sao Paulo, Brazil. Collected by F. X. Williams, March 10, 1924. Types are in the University of Kansas collection.

Doctor Hungerford compared these specimens with type and general material in the British Museum, the Berlin Museum, and the Museum of Vienna, and found them to be different from types located in these collections. This species is perhaps similar to *R. femoralis* Champ., but differs in the armature of the posterior femur. It is somewhat like *R. robusta* n. sp., but differs in color, size, armature of the posterior leg, and the claspers. The claspers are somewhat like those of *R. sinuata* n. sp., but the specimens differ in size, proportional measurements, and the armature of the posterior legs.

Rhagovelia rivale Bueno.

Rhagovelia rivale Bueno. Trans. Am. Ent. Soc., 50:243, 1924.

Antennæ: "15:10:10:10."
Intermediate legs: "Male, 33:24:12:12; female, 33:26:15:13."
Posterior legs: "Male, —:22:3:5."

This is a moderate-sized, black species, in which the winged forms have the pronotum produced posteriorly, the male into an angulate, upturned tip and the female into a long turned-up knob of equal size throughout. The posterior femur of the apterous male is somewhat thickened, and armed near the middle with a long spine followed by four or five short ones. The posterior femur of the female is about equal in size to the intermediate, and is armed as in the male. The connexiva of the female are reflexed, but not to meet above the abdomen.

Length, apterous male, 3.3-3.6 mm.; apterous female, 4.3-4.6 mm.; males winged, 4 mm.; females winged, 4.45 mm; width, all forms, 1.3-1.65 mm.

Notes. I have examined the types and miscellaneous new material from various parts of Kansas. Several of the structures I found to be different from Bueno's description. For instance, in his key Bueno says *rivale* is without a spine on its anterior trochanter; yet in his description he says with a "Stout black spine on the outer aspect." The types, male and female, do not have the anterior trochanters armed. He does not mention the armature of the posterior femur of the female, nor does he mention the proportional measure-

ments of the posterior legs of the female. Furthermore, his proportional measurements differ from what I find—

Antennæ: 18:10:10:8.
Intermediate legs: Male, 33:24:12:12; female, 40:28:15:14.
Posterior legs: Male, 24:24:4:7; female, 30:30:4:7.

Distribution Records. Kansas and Colorado. This species is widely distributed over Kansas, specimens having been taken from seven widely separated counties.

Rhagovelia robusta n. sp.

Antennæ: Male, 24:15:15:15; female, 24:15:16:15.
Intermediate legs: 56:40:16:23; 51:38:16:23.
Posterior legs: 48:44:3:8; 44:40:3:8.

General color brownish-black, clothed with yellow pubescence; legs and antennæ light brown. Sides of body, legs, antennæ and genital segments with longer hairs and a few scattered setæ. Head with median impressed line crossed by a V-shaped suture. Pronotum with a narrow transverse brown band; broader than long (9:8), and broadly rounding behind. Connexivum broad but not reflexed, and with margin of light brown. Acetabula, coxæ, anterior and posterior trochanters, and intermediate trochanters in part, base of antennæ, anterior femur at base, and the basal and lower portion of the posterior femur light brown. Anterior trochanters unarmed; posterior tibia armed with short spur at apex.

Apterous Male. Metanotum slightly emarginate behind and mesonotum covered by pronotum. Genital segments longer than sixth abdominal segment (4:3). Last ventral abdominal segment flattened apically. Posterior femur greatly incrassate and armed with two irregular rows of long teeth of varying size and no definite arrangement. Posterior trochanter armed on inner side with several small teeth. Posterior tibia armed with an irregular row of teeth with one stout tooth near the apex and a stout spur at apex.

Apterous Female. Similar to the male. Posterior femur moderately incrassate and armed with a series of about eight spines. Posterior tibia with a row of regular serrate teeth. Genital segments small.

Length, 4.4 mm.; width, 1.5 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous males and females; all from Villarrica, Paraguay. Collected by Fran. Schade in 1921. All types are in the University of Kansas collection.

Notes. This is the first species of *Rhagovelia* described from this portion of the world, *i. e.,* the east central part of South America. This species is not strikingly different from other South American forms, and yet has some unusual characters. The claspers and genitalia of the male are different, and the color is unusual.

Rhagovelia salina (Champ.).

Trochopus salinus Champion. Biol. Cent.-Am., Het., 2:140, 1898.
Rhagovelia salina Kirkaldy. Ent., 34:308, 1900.
Rhagovelia salina Bueno. *In* Conn. Geo. & Nat. Hist. Survey, Bul. 34, p. 418, 1923.
Rhagovelia salina D. & H. Proc. Biol. Soc. Wash., 40:131, 1927.

This is a small grayish-black species belonging to the group characterized by the sutured-off pronotum. The connexivum is raised and broadly expanded.

The legs are long and with tarsal segment II longer than III. In the males the anterior trochanter is armed with a long acute outwardly directed tooth. The posterior femora are slightly incrassate in the male and armed with one long spine at the middle and row of minute teeth; in the female only feebly incrassated and unarmed or with one or two minute teeth.

Length, 3.2-3.8 mm.; width, 1.4-1.8 mm.

Notes. Four female specimens of this species from Jamaica, B. W. I., were collected by L. C. Perkins, December 24, 1928. This is an unusual-shaped specimen with the connexiva broadly rounded. The body is mottled with a gray powder that comes off readily. The proportional measurements, the shape, and the connexiva separate it from all other species. Proportional measurements are as follows:

Antennæ: 20:12:16:12.
Intermediate legs: 52:41:24:20.
Posterior legs: 29:42:3:8.

Distribution records. Panama, Jamaica.

Rhagovelia sinuata n. sp.

Antennæ: 40:25:27:22.
Intermediate legs: Male, 90:75:23:33; female, 85:68:20:31.
Posterior legs: 85(32):70:6:16; 70:66:6:16.

General color dark brown and clothed with short yellowish pubescence, with longer hairs on the sides of body and legs. Legs and two basal segments of antennæ with a few scattered setæ. Head with usual impressed lines. Pronotum sparsely punctured and of the same color throughout. Connexivum broad, but not reflexed and similar in both sexes. Venter slightly darker brown and with a trace of a longitudinal carina. Sixth ventral abdominal segment excavated each side of middle. Tarsi and apical segments of antennæ darker, almost black. Rostrum black and its tip extending beyond the coxal cavities. Anterior trochanter unarmed; pronotal band almost indistinct with no spots.

Apterous Male. Pronotum obtusely rounded, wider than long (11:8). Last abdominal segment and genital segments with long hairs. Posterior femora greatly incrassate and armed with two rows of spines, the lower row very small in the apical third; first spine of upper row large, followed by four short spines, a very large, stout spine, and a series of shorter spines. Posterior tibia strongly sinuate and armed with two rows of teeth with a large spur at apex. Posterior trochanters armed with several knoblike teeth.

Apterous Female. Venter slightly carinated with the last abdominal segment notched in center apically. Posterior femur incrassate in middle, and armed just beyond the middle with a long spine followed by seven small ones. Posterior tibia with fewer teeth than male, especially near the apex; blunt tooth at apex.

Winged Female. Posterior angle of pronotum about 90 degrees, not elevated at tip. Elytra brownish-black, nervures distinct. Posterior femur moderately incrassate and armed in same manner as apterous female. Posterior tibia slightly but distinctly sinuate and armed as in male. Posterior trochanter with denticulations.

Length, winged female, 5.2 mm.; apterous forms, 4.5 mm.; width, winged female, 1.6 mm.; apterous forms, 1.4 mm.

Holotype, apterous male; allotype, apterous female; morphotype, winged female; paratypes, apterous males and females; all from Banos, Ecuador, collected by F. X. Williams in 1923. Types are in the University of Kansas collection.

Notes. Included in this species are two groups—a lighter reddish-brown form and a brown form. The specimens were compared with type and general material in the European Museum and were found to be distinct. Doctor Hungerford says the reddish specimens (28, 300) are near, but not, *R. fieberi* Guer. type in the Vienna Museum. This species is possibly near *R. femoralis* Champion, but differing in having the posterior tibia sinuate.

Rhagovelia spinigera Champion.

Rhagovelia spinigera Champion. Bio. Cent.-Am., Het., 2:137, 1898.
Rhagovelia spinigera Kirkaldy. Ent., 34:308, 1900.

This is a moderate-sized, brownish-black species, of which only the winged female is known. The pronotum is produced posteriorly into a long, semierect spiniform process. The legs are comparatively slender, with the posterior pair short. The intermediate femur is "curved in front and concave within, abruptly compressed at the middle." Posterior femur is slightly thickened and is armed with a long spine at the middle, followed by 5 or 6 shorter teeth apically. Posterior tibia is armed at apex with a straight spur. The intermediate tarsus has segment two shorter than three. Length, 4.5 mm.; width, 1.6 mm.

Notes. There are two winged females in the University of Kansas collection bearing the label "San José, C. R., January, 1905, P. Biolley, collector." In addition to the above characters I find the posterior femora to have a second row of minute teeth. The first genital segment has a carina beneath that broadens apically. The intermediate coxæ are dark brown. Formulæ:

Antennæ: 34:20:19:18.
Intermediate legs: 68:46:22:32.
Posterior legs: 56(12):60:7:14.
Pronotum wide 60, long 76 (including process).

The above specimens were compared by Doctor Hungerford in 1928 with the types in the British Museum and found to be the same species.

Distribution Records. Guatemala, Costa Rica.

Rhagovelia spinosa n. sp.

Antennæ: 20:11:12:10.
Intermediate legs: 36:27:14:18.
Posterior legs: 26:31:3:7.

Apterous Male. General color black, densely clothed with light brown pubescence and with numerous long hairs on body, legs, and antennæ. Base of first antennal segment, anterior coxa and trochanter, posterior trochanter in part, and a spot near the base of posterior femur, brown. Venter gray with lighter pubescence. Pronotum sutured off from mesonotum. Posterior tibia unarmed. Hairs on the posterior acetabula forming a large, stout, spinelike group. Anterior trochanter armed with a very long prominent hair.

Abdomen terminating ventrally in a large, stout, slightly curved spine. Posterior femur slightly incrassate, being about equal with intermediate femur

at base; armed at apical third by one spine, followed by about three minute teeth. Genital segments large. Length, 2.6 mm.; width, 1 mm.

Holotype, apterous male; paratype, apterous male; both from Tena, near Oriente, Ecuador, collected by F. X. Williams, March 29 to April 10, 1923. Types are in the University of Kansas collection.

Notes. This species belongs in the group characterized by the sutured-off pronotum. It may be distinguished from other species of the group by the proportional measurements, the very hairy body, and the spine on the posterior edge of the abdomen. This species is related to *festæ* Kirkaldy, but differs in the proportional measurements of the antennæ, in having the posterior femur armed, and in the spine on the underside of the abdomen.

Rhagovelia tayloriella Kirkaldy.

Rhagovelia tayloriella Kirk. Ent., 33:72, 1900.
Rhagovelia tayloriella Kirk. Ent., 34:308, 1900.

Antennæ: 30:20:18:17.
Intermediate legs: 42:30:14:16.
Posterior legs: 30:27:3:6.

This is a large black species belonging to the *collaris* group that is characterized by the anterior tibia being dilated and excavated beneath. The posterior femur of the males is strongly incrassate and armed with ten or eleven strong teeth from its center to apex; tibia and trochanter are denticulate. The posterior femur of the female is moderately incrassate and armed with one large and two or three small teeth. The connexiva are semivertical and much narrowed in from the base at first, afterwards continuing subparallel. In the winged forms the male has the pronotum produced posteriorly into a short acute porrect spine, while in the female it is produced into a long stout process, that "arises at an angle of 45 degrees, curves around near its apex and is then deflected slightly downwards."

Length, 5 mm.

Notes. This species is related to *R. collaris* (Burm.), but may be separated from that species by its straight posterior tibia. *Tayloriella* may be distinguished from the brighter marked *collaris* var. *pulchra* n. var. by the comparative sizes of the antennal segments.

Distribution Record. Jamaica.

Rhagovelia tenuipes Champion.

Rhagovelia tenuipes Champion. Biol. Cent.-Am., Het., 2:137, 1898.
Rhagovelia tenuipes Kirkaldy. Ento., 34:308, 1900.
Rhagovelia tenuipes D. & H. Proc. Biol. Soc. Wash., 40:131, 1927.

Antennæ: 34:18:18:16.

This is a moderate-sized, black species belonging to the group characterized by the sutured-off pronotum. The legs are very long and slender, with the posterior tibia unarmed at its apex. The intermediate leg has tarsal segment II much longer than III. The posterior femur is normal in thickness and armed with a long acute spine at the middle, followed by a row of very short teeth.

Length, about 4 mm., probably.

Distribution Record. Mexico (Tabasco).

Rhagovelia trista n. sp.

Antennæ: 32:18:20:18.
Intermediate legs: 68:48:23:28.
Posterior legs: 56:42:3:10.

General color black, covered with brownish pubescence, and with longer hairs on sides of body, legs, and the two basal segments of the antennæ. Edge of connexivum pubescent, dorsum of abdomen nearly glabrous. Pronotum short (8 wide, 4 long) and obtusely rounded behind; mesonotum truncate behind (8 wide, 3 long); metanotum broadly truncate behind, one-third as long as mesonotum. Base of antennæ, anterior and posterior trochanters in part, and the base of the anterior femora, flavous to dark yellow. Pronotum with a pale band and the usual spots each side of the middle. A row of punctures on and parallel to the anterior margin of pronotum resemble a suture, giving the appearance of a minute segment. Anterior trochanters unarmed. Venter grayish-black; last abdominal segment black.

Apterous Male. Posterior femora incrassated and having a long spine at the basal third, followed by three distinct, sharp teeth and four smaller ones. Posterior tibiæ somewhat sinuous, armed with teeth decreasing in size apically; apex with a sharp spur. Connexiva broad, slightly reflexed.

Apterous Female. Much as in the male. Connexivum nearly vertical. Posterior femur (as in male) armed with one long, sharp spine, followed by three somewhat smaller but still distinct spines, and then four minute teeth. Genital segments small and bluntly rounded.

Length, male, 3.3 mm.; female, 3.6 mm.; width, 1-1.2 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous males and females; all collected at Mera, Ecuador, by F. X. Williams, in 1923. Also specimens labeled from Ecuador, and from Banos, Ecuador, by F. X. Williams. Types are in the University of Kansas collection.

Comparative Notes. This species was compared with type and general material in the British Museum, in the Museum of Vienna, and in the Berlin Museum. No similar specimens were found.

This species is not similar to any of the known species. It is somewhat like *R. williamsi* n. sp., but differing from it in color markings, armature of the posterior femur, and some in the structure of the pronotum.

Rhagovelia trailii (White).

Neovelia trailii White. Jour. Linn. Soc. Lond., Zoöl., 14:487, 1879.
Rhagovelia trailii Kirkaldy. Ent., 34:308, 1900.

The original description of this species is as follows:

"Nigro-brunea, pubescentia confera concolori vestita, capite, antennis, pedibus, pronoto postico abdominisque lateribus parce nigro-setulosis; pronoto antice, prostethio, connexivo, ventre ad medium, antennarum articulo primo ad basin, coxis, trochanteribus, femorum anticorum macula et vitta subtus, femorum posticorum basi et spinis ad basin flavido-fulvis; pronoti carina centrali subelevata plus minus, præcique antrosum, rufo-fulva. Male long. 4, lat. 1½ millim.

"Hab. Brasiliam borealem. (Manaos, August, 1874, 'at light,' J. W. H. Trail.)"

Doctor Hungerford agrees with Kirkaldy that this species is a *Rhagovelia*. While examining types in the British Museum, Doctor Hungerford found that none of the specimens from the University of Kansas collection belongs to this species.

Rhagovelia uncinata Champion.

Rhagovelia uncinata Champ. Biol. Cent.-Am., Het., 2:135, 1898.
Rhagovelia uncinata Kirkaldy. Ento., 34:308, 1900.

Antennæ: 30:20:18:16.

This is a moderately large, reddish-black species belonging to the group that is characterized by having the posterior tibia armed with a curved hook. The terminal genital segment of both sexes is produced into a sharp spine at apex. The intermediate tarsi has segment III much longer than II. "Posterior femur (of male) moderately incrassate, armed with seven or eight acute, curved teeth, the two inner ones much longer than the others and widely separated (one at the middle and one at about the basal third)." Posterior femora of the female are less incrassate than the male and armed similarly.

Length, 4-5.1 mm.; width of winged forms, 1.5-2 mm.; of apterous forms, 1.25-1.5 mm.

Distribution Record. Panama.

Rhagovelia varipes Champion.

Rhagovelia varipes Champ. Biol. Cent.-Am., Het., 2:133, 1898.
Rhagovelia varipes Kirkaldy. Ent., 34:308, 1900.

Antennæ: 30:16:—:—.

This is a large black species that Champion describes in part as follows: "Pronotum abbreviated and rounded behind, with indications of a median ridge anteriorly. Abdomen gradually narrowing from the base; the first and second ventral segments strongly longitudinally carinate down the middle, the sixth segment deeply triangularly emarginate at the apex, leaving the first genital segment exposed. Anterior tibiæ slightly hollowed at the apex beneath. Intermediate tarsi with the second joint slightly longer than the third. Posterior femora greatly incrassate, armed with numerous teeth, which are placed in two rows along the center, those of the upper row unequal in length, there being three longer teeth towards the middle and two beyond it; posterior tibiæ denticulate and strongly sinuous, the teeth along the apical third slightly longer than the others, the apex unarmed."

Length, nearly 6 mm.; width, 1.75 mm.

Distribution Record. Mexico.

Rhagovelia vivida (White).

Velia vivida White, B. Jl. Linn. Soc., Zoöl., 14:486.

Dr. H. B. Hungerford, after a careful study of White's type of *Velia vivida* in the British Museum, finds it to belong to the genus *Rhagovelia*. The type is a very large female (8 mm.) from Nicaragua. Hungerford's notes on the specimen are as follows:

"Is dark gray in color with lighter gray patches on sides of thorax and abdomen; yellow band gray-margined on collar of thorax. Margin of connexi-

vum yellow—*not* spinous pointed. Shoulders with stout, erect, sharp, somewhat backwardly directed elevations. Hind femur with two stout spines, femur *not* greatly incrassate."

Rhagovelia whitei (Breddin).

Neovelia whitei Breddin. Jahrb. Nat. Ver. zu Magee., p. 14, 1898.
Rhagovelia whitei Kirkaldy. Ento., 34:308, 1900.

"*Male, Apterous.* Antennarum articulus primus secundo distincte longior (5:3), articulo secundo apicalibus duobus, gracilibus robustiore. Pronoto carina mediana subelevata destituto, medico convexo, pone humeros late-rotundato producto et retrorsum fere acetabulorum intermediorum marginem apicalem æquante; pronoto toto latitudine humerali quinta vel quarta fere parte breviore. Prothoracis marginibus omnino deletis pronotum paullatim atque indistincte in convexitatem acetabulariam transit; prostethio postico supra coxæ linea intramarginali curvata punctorum impressorum subtilium fuscorum notato. Spinulis dimidii apicallis femorum posticorum parvis, omnibus fere æquilongis, sub apicem extus spinula unica maiore.

"Nigra, opaca, ubique pilis brevibus, adpressis, sordide ferruginescentibus dense vestita; femoribus posticis subtus tibiisque omnibus longius pilosis; capite supra, antennarumque articulis basalibus setis nonnullis suberectis instructis, femoribus anticis subtus serie eiusmodi setarum erectarum et extus et intus, femoribus intermediis serie unica setarum semicumbentium munitis. Capite (verticis basi excepta), antennarum articuli primi fere dimidio basali, rostro (apice excepto), pronoti margine late antice, pectore (sternis meso- et metastethii his sordide castaneis, exceptis), coxis et trochanteribus omnibus, connexivi margine, segmenti ventralis sexti medio late annuloque basali segmenti genitalis ferrugineo-luteis. Trochanteribus anterioribus apice annulo, intus obsoleto, nigro. Femoribus amnibus (Intermediis sordide) ferruginescenti-luteis, anticorum vitta lata dimidii apicalis supra atque extus, intermediorum parte omni superiore (vel posteriore), posticorum macula magna, submicante partis superioris atque anterioris, basin non attingente, nigris. Tibiis ab infero visis sordide ferruginescentibus, a supero visis nigris vel fuscis.

"Long., 4¾ mm.

"'Lagoa santa' (coll. Instituti Zoölogici Halensis)," South America.

Rhagovelia williamsi n. sp.

Antennæ: 21:12:13:13.
Intermediate legs: 47:34:12:20.
Posterior legs: 38:32:2:7.

General color brownish black, clothed with yellow pubescence. Pronotum with narrow transverse silver-gray band. Legs, sides of body, and two basal antennal segments with longer hairs and a few scattered setæ. Basal antennal segment swollen at a point two-thirds of its length and with three long setæ at this point. Pronotum broader than long (10:6), obtusely rounded behind and covering the mesonotum; metanotum emarginate behind. Coxæ, acetabula, anterior and posterior trochanters, base of anterior femur, and base of antennæ, flavous. Venter gray-black. Anterior trochanter and posterior tibia unarmed.

Apterous Male. Genital segments large, being as long as the last two abdominal segments. Posterior femur greatly incrassate, armed at the basal third with one long spine, at the middle with a longer spine, and this followed by seven shorter, stout spines; spines in two distinct rows. Last ventral segment of abdomen and first genital segment brown.

Apterous Female. Body cylindrical; connexivum nearly vertical, its edge with long hairs, and apex ending in a sharp, stout spine, extending back half

the length of the first genital segment. First and fourth abdominal segments gray, as are also the lateral margins of the second and third segments, and all dorsal abdominal sutures. Posterior femur strongly incrassate and armed much as the male. First genital segment on the ventral surface carinated and slightly depressed just beyond the base.

Length, 3.6-3.7 mm.; width, 1.2 mm.

Holotype, apterous male; allotype, apterous female; paratypes, apterous males and females; all collected by F. X. Williams, February 28, 1923, from Tena, Ecuador. Types are in the University of Kansas collection.

Comparative Notes. This species is similar *to R. amazonensis* n. sp., but differs in the large genital segments of the male, the size of the male claspers, and in the female the spine-like projections of the connexiva.

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EXPLANATION OF PLATES.

(51)

PLATE I.

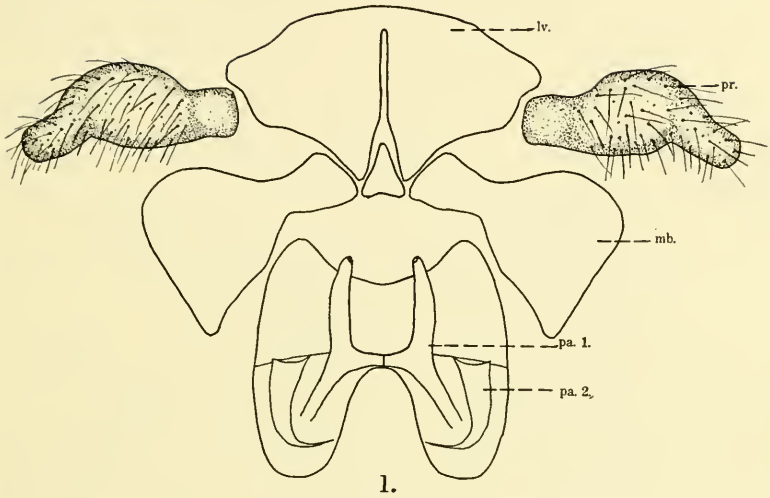
THE GENITALIA OF RHAGOVELIA.

Semidiagrammatic drawings of the genitalia, illustrating the structures used in classification.

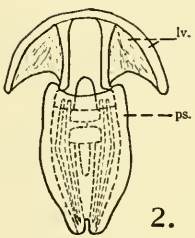
1. Claspers and internal genitalia removed from hypandrium and partially flattened.
2. Lever and penis removed from hypandrium in their natural position.
3. The genital segments.
4. The internal genitalia and hypandrium from above in natural position.

Structures: *lv,* lever; *mb,* membrane; *ps,* penis; *pr,* clasper; *pa* 1, appendage of penis 1; *pa* 2, appendage of penis 2; *an,* anal lid; *hy,* hypandrium; *x,* marking point of attachment of lever and clasper to hypandrium.

PLATE I.



1.



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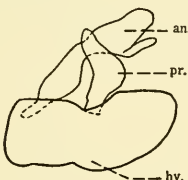

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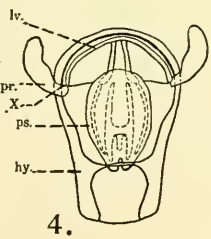


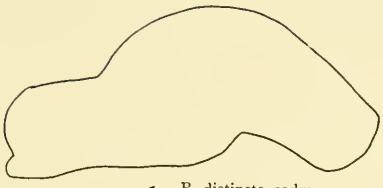
4.

PLATE II.

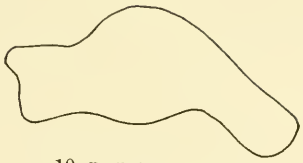
VARIETIES OF *Rhagovelia distincta* Champion.

1. Clasper of *cadyi* n. var.
2. Penis appendage 1. of variety *proxima* n. var.
3. Penis appendage 1. of variety *arizonensis* n. var.
4. Penis appendage 1. variety *valentina* n. var.
5. Clasper of variety *modesta* n. var.
6. Penis appendage 1. of variety *cadyi* n. var.
7. Penis appendage 1, of variety *modesta* n. var.
8. Penis appendage 1. of variety *harmonia* n. var.
9. Penis appendage 1. of *distincta* Champ.
10. Clasper of variety *harmonia* n. var.
11. Clasper of variety *proxima* n. var.
12. Clasper of variety of *excellentis* D. & H.
13. Clasper of variety *arizonensis* n. var.
14. Clasper of variety *valentina* n. var.

PLATE II.



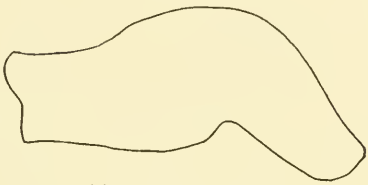
1. R. distincta cadyi



10. R. distincta harmonia

R. distincta proxima
2.

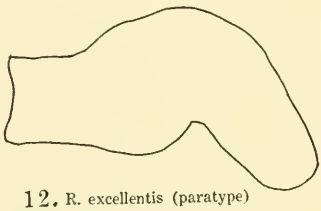
6.
R. distincta cadyi



11. R. distincta proxima

7.
R. distincta modesta

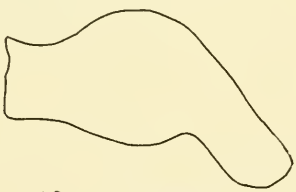
3. R. distincta arizonensis



12. R. excellentis (paratype)

8.
R. distincta harmonia

4. R. distincta valentina



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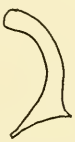
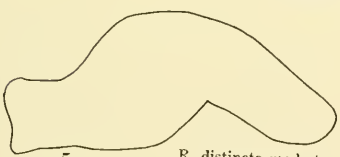
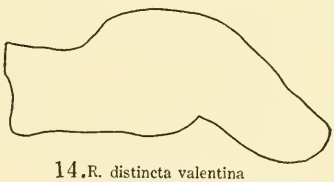


9. R. distincta



5.
R. distincta modesta



14. R. distincta valentina

PLATE III.

CLASPERS.

1. *Rhagovelia choreutes* Hussey.
2. *Rhagovelia robusta* n. sp.
3. *Rhagovelia arctoa* Bueno.
4. *Rhagovelia flavicincta* Bueno.
5. *Rhagovelia bcameri* n. sp.
6. *Rhagovelia oriander* Parshley.
7. *Rhagovelia castanea* n. sp.
8. *Rhagovelia lucida* n. sp.
9. *Rhagovelia obesa* Uhler.
10. *Rhagovelia rivale* Bueno.

PLATE III.

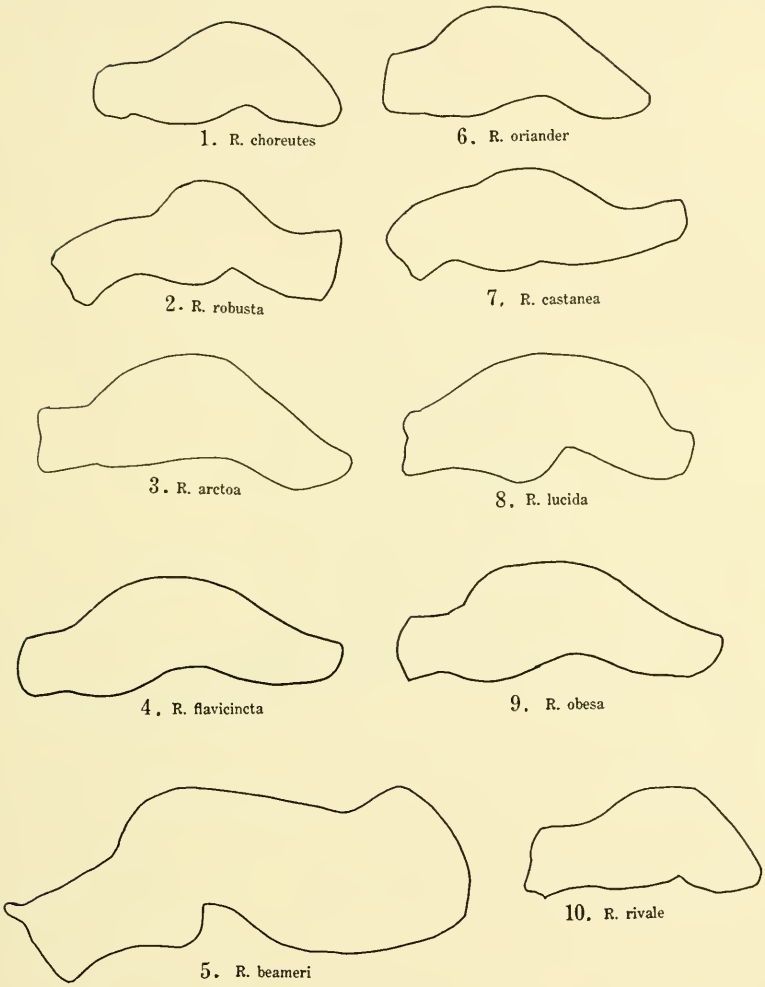

1. R. choreutes
6. R. oriander
2. R. robusta
7. R. castanea
3. R. arctoa
8. R. lucida
4. R. flavicincta
9. R. obesa
5. R. beameri
10. R. rivale

PLATE IV.

CLASPERS.

1. *Rhagovelia gigantea* Gould.
2. *Rhagovelia amazonensis* n. sp.
3. *Rhagovelia williamsi* n. sp.
4. *Rhagovelia relicta* n. sp.
5. *Rhagovelia angustipes* Uhler.
6. *Rhagovelia obscura* n. sp.
7. *Rhagovelia longipes* n. sp.
8. *Rhagovelia confusa* n. sp.
9. *Rhagovelia sinuata* n. sp.
10. *Rhagovelia spinosa* n. sp.
11. *Rhagovelia trista* n. sp.
12. *Rhagovelia collaris* (Burm.).
13. *Rhagovelia insularis* Champion.

PLATE IV.

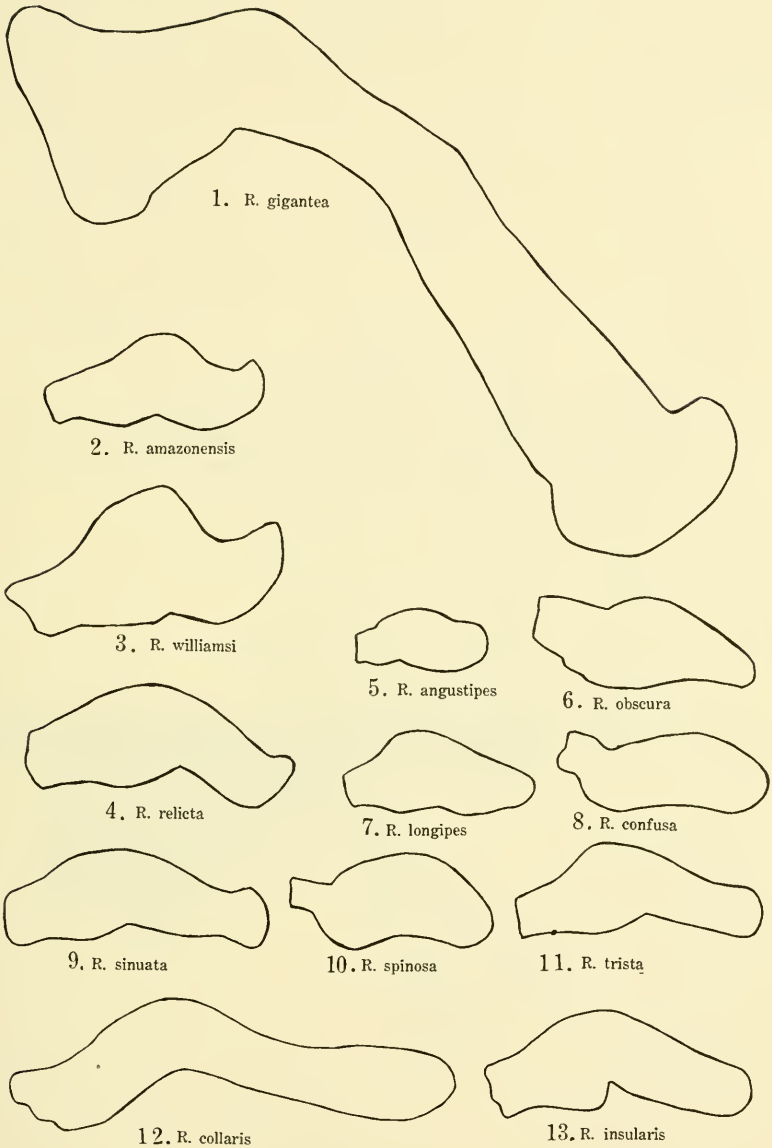

1. R. gigantea
2. R. amazonensis
3. R. williamsi
5. R. angustipes
6. R. obscura
4. R. relicta
7. R. longipes
8. R. confusa
9. R. sinuata
10. R. spinosa
11. R. trista
12. R. collaris
13. R. insularis

PLATE V.

STRUCTURAL CHARACTERS.

1. Penis appendage l. of *Rhagovelia angustipes* Uhl.
2. Penis appendage l. of *Rhagovelia spinosa* n. sp.
3. Penis appendage l. of *Rhagovelia longipes* n. sp.
4. Penis appendage l. of *Rhagovelia obscura* n. sp.
5. Pa l. of *Rhagovelia confusa* n. sp.
6. Pa l. of *Rhagovelia choreutes* Hussey.
7. Pa l. of *Rhagovelia obesa* Uhler.
8. Pa l. of *Rhagovelia rivale* Bueno.
9. Pa l. of *Rhagovelia flavicincata* Bueno.
10. Pa l. of *Rhagovelia oriander* Parshley.
11. Pa l. of *Rhagovelia arctoa* Bueno.
12. Third tarsal segment of intermediate leg of a *Rhagovelia,* showing the characteristic cleft segment with the plumose hairs arising from the base of this cleft.

PLATE V.

1. R. angustipes

4. R. obscura

6. R. choreutes

2. R. spinosa

7. R. obesa

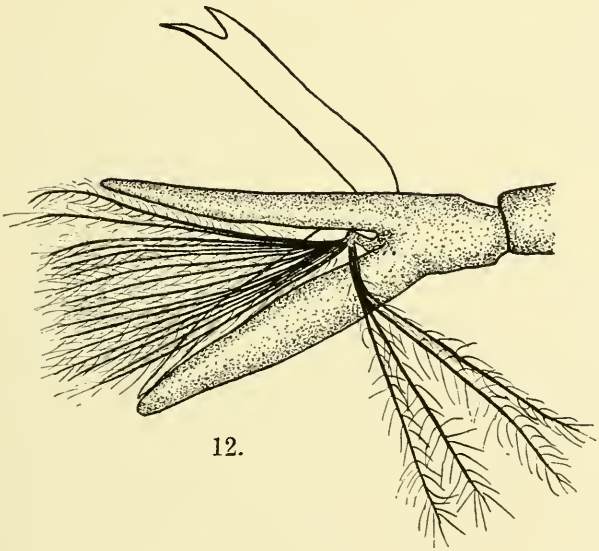
3. R. longipes

5. R. confusa

8. R. rivale

9. R. flavicincta

10. R. oriander



12.

11. R. arctoa

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The Genus *Rheumatobates* and Notes on the Male Genitalia of Some Gerridæ (Hemiptera, Gerridæ).*

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INTRODUCTION.

THE genus *Rheumatobates* is perhaps the most remarkable group of insects in the order Hemiptera. It is included in that very interesting family commonly known as the water striders. As none of the species is much over three millimeters in length the amateur often mistakes them for the immature stage of some of the larger striders and seldom gives them any attention. They are therefore usually taken only by the collector particularly interested in the group. As a result there are few specimens in our museums and the known distribution is very limited.

HISTORICAL ACCOUNT.

The genus was erected by E. Bergroth in 1892. The preceding year Rev. J. L. Zabriskie, in collecting aquatic insects at Flatbush, Long Island, found among his specimens a very curious one. Soon afterward C. V. Riley published a description and illustration of it in *Insect Life* without giving it a name. Upon the strength of this description Bergroth based his *Rheumatobates rileyi*. He gave as generic characters the curiously formed antennæ and posterior legs and the presence of two ocelli. Ocelli, however, are absent in all species of the genus, and since that time two species have been added with normal hind legs. In 1894 Uhler described a species

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† ACKNOWLEDGMENT.—The writer wishes to express his sincere appreciation for the helpful suggestions and kindly criticisms of Dr. H. B. Hungerford, under whose direction this work was undertaken. Thanks are also due to J. R. de la Torre-Bueno for determined material and to various European museums for loans and gifts to Doctor Hungerford.

which he called *Hymenobates imitator*. This was the winged form of Meinert's *R. bergrothi* described in 1895. Thus Meinert's species and Uhler's genus fell into synonymy and the species became *R. imitator* (Uhler). At the same time Meinert described *R. tenuipes*, which is one of the two species with normal hind legs; the other was described in 1908 as *R. præposterus* by Bergroth from the collection of Prof. James S. Hine. Doctor Riley was already familiar with *tenuipes* Mein., but he was mistaken in regarding it as the "normal" form of the apparently "abnormal" *rileyi* Berg. He was evidently misled by the fact that they are often found associated together, and as the females are quite similar the mistake was easily made.

BIOLOGY.

Little is known regarding the biology of *Rheumatobates*. At first these insects were thought to occur only on swiftly flowing streams, but since then they have been collected from the backwaters of sluggish streams and in the West even from the standing muddy waters of ponds. They are gregarious in habit, sometimes occurring in large numbers, often in association with other members of the Gerrid family, particularly *Trepobates pictus* H. Sch. They are very active; their long intermediate legs propel them over the water with surprising speed. Grace O. Wiley writes that "The winged forms are very agile and hard to capture; they have the habit when disturbed of skimming over the surface of the water in astonishing leaps and bounds, aided no doubt by their wings even when truncated." Doctor Hungerford has made the following observations with regard to their habits: "In Kansas *R. rileyi* (var. *palosi* Blatchley) is common enough on the muddiest ponds and pools. Three summers have failed to disclose the nature of the oviposition. The ovipositor suggests that the eggs are laid in the tissue of a plant.

"They feed upon insects dropped upon the water, and if watched in a pool teeming with ostracods they can be seen to scoop them out of the water and carry them on the upturned tip of the beak."

He describes the eggs as being .728 mm. in length and .208 mm. in width. Elongate-cylindrical in shape, one end bluntly pointed and the other end rounded, bearing a short micropyle.

Various functions have been ascribed to the curiously formed antennæ; the most logical one seems to be that of clasping organs used during copulation. In all the species, except possibly those from South America, they seem to be well fitted to clamp around the antennæ of the female. As the females have normal antennæ

it seems highly probable that they serve some secondary sexual function. It has been suggested, also, that they are prehensile in function, serving to catch and hold the insects and other organisms upon which they feed. However, if this were true the females would need this type also.

Nearly all of the species are known to be dimorphic, occurring in both the winged and wingless form. More extensive collecting will probably prove all species to be dimorphic. Generally the apterous form is the more common, although the macropterous form is very numerous at times. The winged form differs from the wingless mainly in the size and shape of the pronotum, which is greatly enlarged to cover the base of the hemelytra and almost the entire mesonotum. The venation of the hemelytra is greatly reduced, the costal margin is thickened and sometimes fringed with short hairs. The membrane is separated from the corium by a whitish vein which extends entirely across the wing; there is also a whitish vein running the entire median length of the membrane. A vein follows the entire margin of the membrane, forming a loop. The clavus is quite narrow. The membranous hind wings are shorter and narrower than the hemelytra, but they have approximately the same venation. As in other Halobatinæ, the winged individuals often break off their wings leaving only the corium and clavus, thus exposing the tip of the abdomen. The membrane always breaks off along the whitish vein which extends across its base.

Another curious difference between the winged and wingless forms is the presence of from five to eight long stiff hairs on the dorsal surface of the genital segment. They are arranged in a single or double transverse row, depending upon whether the hairs are few or many. They are vertical or bent slightly backward. When the wings are folded back they rest upon these hairs. Only the males have these hairs, and they never occur on the wingless forms of either the males or females.

DISTRIBUTION.

All of the species thus far described have been collected in the Western Hemisphere. Their presence in Europe seems doubtful as they have never been reported by any of the Hemipterists of that continent. It is interesting to note that for almost twenty years after the first species was described no specimens were taken far from the sea. Since that time *R. rileyi var. palosi* Blatchley has been found as far west as the Rocky Mountains and from Minnesota

in the North to Arkansas in the South. *R. imitator* (Uhler) and its variety *meinerti* var. new, occurs in the Lesser Antilles. *R. crassifemur* Esaki, *R. crassifemur* var *esakii* var. new, and *R. klagei* sp. new occur in Argentina, Paraguay and Brazil, South America. *R. præposterus* Bergroth has been collected only from Guatemala of Central America. All of the other species are found in the United States. The distribution of the various species seems to be quite limited with the exception of *R. rileyi* var. *palosi* Blatchley as given above. This is probably due more to the lack of extensive collecting than to a local distribution.

STRUCTURAL CHARACTERS USED.

The structure of the antennæ, the posterior legs, and in one species the structure of the middle tibiæ, form the basis for separation of the species within the genus. In the North and Central American species the third segment of the antennæ bears a peculiar spongy pit or fossa which varies to a considerable extent in size, shape and in the degree and manner of armature. The position of the tooth on the fourth antennal segment is of some value. The hairs on the intermediate legs and the hairs and spines, and especially the manner and degree of incrassation, of the hind legs easily separate some species.

The genitalia of four species were dissected and good specific characters were found. These are, however, not essential to the separation of the species and will be described in detail under the studies of the genitalia of some male Gerrids.

THE SPECIES OF *RHEUMATOBATES* BERGROTH.

KEY TO THE MALES.

A. Hind legs normal.
  B. Tibiæ of middle legs strongly arched at the base, then straight to the tip. *præposterus* Bergroth.
  BB. Tibiæ of the middle legs straight..... *tenuipes* Meinert.
AA. Hind legs incrassated, curved or deformed.
  B. Hind trochanter smaller than hind coxæ.
    C. Hind femora hairless or at most with very short fine hair along the whole inner margin.
      D. Posterior margin of middle femora with a row of long, straight hairs, base and tip bare..... *hungerfordi* Wiley.
      DD. Middle femora hairless..... *trulliger* Bergroth.
    CC. Hind femora with long hairs on the basal third of the posterior margin.
      D. Spur on terminal antennal segment beyond the middle... *rileyi* Bergroth.
      DD. Spur on terminal antennal segment before the middle. *rileyi* var. *palosi* Blatch.
  BB. Hind trochanters incrassated, longer and larger than hind coxæ.
    C. The hind trochanter inserted beyond the base of the femur.
      D. A dense tuft of bristles extending forward from the basal extremity of the hind femora..... *klagei* sp. new.

DD. Basal extremity of hind femora bare.
E. Terminal antennal segment with a row of a strong setæ on the dorsal margin near the apex.
crassifemur var. *esakii* var. new.
EE. Terminal antennal segment relatively bare....*crassifemur* Esaki.
CC. Distal end of trochanter joining basal end of femur.
D. Intermediate tibiæ sinuate with long hairs at the middle.
imitator Uhler.
DD. Intermediate tibiæ straight, no long hairs at the middle.
imitator var. *meinerti* var. n.

RHEUMATOBATES Bergroth.

Rheumatobates Bergroth. Insect Life, Wash. IV, p. 321; 1892.
Hymenobates Uhler. Proc. Zoöl. Soc. London, p. 214; 1894.
Halobatopsis Ashmead. Can. Ent. XXIX, p. 56; 1897.

Description of the genus from Blatchley's Hemiptera of Eastern United States:

"Very small oblong or oblong-oval species having the head quadrate wider across the eyes than long, its blunt tylus projecting forward between the bases of the antennæ; eyes very large, coarsely granulated; antennæ of males curiously curved and armed with several short, acute spines; pronotum much wider than long, its front and hind margins truncate; mesonotum (brachypterous form) subquadrate, three or more times as long as pronotum; elytra rarely present; front legs short, stout, the tibia less than half the length of femur; basal joint of tarsi very small, second joint with apical half flattened beneath and claws inserted near the middle; middle legs very long and slender, tibia and usually the femur of male fringed on the inner side with long hairs."

Rheumatobates rileyi Bergroth.

Rheumatobates rileyi Berg. Insect Life, Wash., IV, p. 321; 1892.
Halobatopsis beginini Ashmead. Can. Ent. XXIX, p. 56; 1894.

This is the first species described and is the one upon which the genus was erected. Blatchley's description is as follows:

"Length, 2.8-3 mm. Oblong robust, narrowed behind. Above velvety black; a transverse median spot on the pronotum, a diamond-shaped median spot on the mesonotum, a rounded one above the middle coxæ, the front femora and the reflexed connexivum yellow, antennæ, beak and middle and hind legs fuscous brown, the bases of the antennals and the femora yellow, under surface pale yellow, abdomen often with a dusky tinge. Male with first joint of antennæ gradually thickened from the base, armed beneath at apical third with one or two short spines; second joint very short-armed with a slender spine near the base; third strongly curved with a shallow spinose fossa at apical third; fourth with apical half curved acute, armed in front of the middle with a strong tooth. Middle tibia of male fringed with short hooked hairs on inner side of basal half; hind femora of male swollen, strongly curved and fringed within on basal third with a tuft of long hairs, the apex also with two tufts of hairs; hind tibia narrowed and slightly curved at the base, fringed above on inner side with short, stiff hairs and with a tuft of long hairs glued together projecting backward from inner side of basal fourth. Female with antennæ and legs unmodified, the former beset with a few long, stiff bristles."

Notes. The mesosternum is unicolorous, varying from light yellow to dark yellow. The color variation in this species is much less than in *rileyi var. palosi* Blatchley. Even here, however, the mesonotal spot becomes smaller and darker and almost disappears entirely in some individuals.

Distribution. The distribution seems to be very limited, having been taken only near the Atlantic coast from New York to the District of Columbia.

Rheumatobates rileyi var. *palosi* Blatchley.

Rheumatobates rileyi var. *palosi* Blatchley. Hemip. of East. U. S.; 1926.

Blatchley gives the following description for this variety:

"Differs from *rileyi* in having the body of the male more slender, yellow spot on the mesonotum only about half the width of that of pronotum; tooth of apical joint behind middle; hind tibiæ straighter, more slender, without tubercle on apical half and with a fringe of long, black hairs along the entire inner side. Female with mesonotum wholly black."

Notes. The hairs on the head are shorter, while those on the inner margin of the hind femur are longer and more numerous than those in *R. rileyi,* Bergroth. The color characters given in the above description hold only for a very small number of individuals in the variety. Doctor Hungerford's collection contains specimens from a wide range of localities and the variation in color is remarkable. The spot on the mesonotum is not at all constant in size, shape or color. Specimens from Hodgeman county, Kansas, have the spot almost a creamy white, covering more than half the width of the mesonotum, only slightly narrower than the spot on the pronotum. Even the black band on the anterior margin of the mesosternum is broken between the anterior legs. Some of the females taken at the same place not only have a mesonotal spot, but it is even larger than that of the male; it runs the full length of mesonotum. The metanotum also has an irregular dark yellow spot. At the other extreme are specimens from Douglas Lake, Michigan, which, except for a small brown pronotal spot, are entirely black above. These specimens are also remarkable for their very large size, being by far the largest individuals in the genus. The males measure fully 3.1 mm. and the females 3.4 mm. in length, while the specimens mentioned above are only 2.7 mm. and 3 mm. in length for males and females respectively. Between the two extremes in color almost every gradation exists. Other specimens from Kansas have the pronotal and mesonotal spots brown, the latter very faint in some cases. Specimens taken in Minnesota are just as black as those from Michigan, but they are of normal size. In the past color has played a very important part in separating the species, especially the females. Where such a range of color exists it can be of little or no use in identification.

Distribution. Rh. rileyi var. *palosi* Blatchley seems to enjoy a wider distribution than any other member of the genus. It has been taken in at least six states. These are: New York, New Jersey, Michigan, Minnesota, Arkansas and Kansas.

Rheumatobates tenuipes Meinert.

Rh. tenuipes Meinert. Ent. Meddel. V, p. 7; 1895.
Rh. tenuipes Bergroth. Ohio Natur. VIII, p. 381; 1908.

Description according to Bergroth's key:

"Mesonotum scarcely (male) or slightly (female) broader than long, median yellow spot distinctly narrower than pronotal spot. Mesosternum yellow with the anterior margin and two posteriorly diverging bands brownish-black, dilated near the anterior margin. Second male antennal joint beneath at the base

with a small tubercle bearing a fine hair (not visible when joint is strongly deflected), the curved basal part of the third joint one-half the length of the whole joint, the spongy pit occupying the apical half with a long slender spine at its base, fourth joint scarcely shorter than third, curved near the base and at the extreme apex with the curved spine on the basal half. Middle tibiæ in the male fringed with short hooked hairs on the inner side, almost to the apex. Hind legs in both sexes simple, straight and hairless."

Notes. The general form and appearance of this species is very much like that of *R. rileyi* Bergroth, except that the hind legs are normal. The third antennal joint is a little shorter and the fossa or spongy pit occupies about one-half the segment, while in *rileyi* it covers only a little more than the apical fourth; the tooth on the fourth segment is even nearer the base than in *rileyi* variety *palosi,* Blatchley. Except for the ventral spine, the first segment is entirely free from hairs and those on the third and fourth segments are much shorter and lighter. The macropterous male has the pronotum expanded as in other winged members of the genus. It differs, however, in being distinctly longer than wide, and in having about six or eight long, stout, black hairs scattered over each side of the anterior region. There are also a number of pits on each side of the middorsal line between the two hairy regions. The entire costal margin of the corium bears a row of hairs. These are about twice as long as those on *rileyi.*

Distribution. The distribution of this species is the same as that of *rileyi* Bergroth, with which it often associates. It has also been taken in Georgia.

Types. One of Meinert's types taken by O. Heidemann at Glen Echo, Maryland, is in the Snow collection, Kansas University, Lawrence.

Rheumatobates imitator (Uhler).

Hymenobates imitator Uhler. Proc. Zoöl. Soc., London, p. 214; 1894.
Rheumatobates bergrothi Meinert. Ent. Meddel. V, p. 7; 1895.

Description taken from Bergroth's key.

"Mesonotum much broader than long. Second male antennal segment with a slender spine beneath near the base; third segment with a strong triangular tooth at the basal end of the not dilated spongy pit, the lower margin of the pit beset with stiff hairs; fourth segment much shorter than third, straight, unarmed. Middle coxæ in the male not thicker than the hind coxæ; trochanter many times smaller than the hind trochanter; femora fringed with long hairs on the inner margin near the base and apex; the remaining part glabrous; tibia somewhat curved in the middle where they are thickest, from the base to near the middle fringed on the inner side with short curved hairs, then along a shorter space with long hairs. Hind trochanter of the male excessively incrassated, much broader and thicker than the coxæ and femora, armed with a stout spine on the upper side, longly and thickly pilose on the inner side; femora incrassated and curved with a strong tooth on the upper side before the middle and a curved chitinous process on the inner side behind the tooth, near the apex on the same side with another linear chitinous process (apparently made up of hairs glued together); tibia rather stout, slightly curved, the inner margin with scattered hairs from the base to near the middle, behind the middle fringed with long hairs."

Notes. This species is dimorphic, occurring in both the apterous and macropterous forms. First described under *Hymenobates* by Uhler, and later as *Rh. bergrothi* by Meinert, who described the apterous form as a new species.

Rheumatobates imitator var. *meinerti* var. new.

Size. Male, length, 2.7 mm.; width, 1.3 mm.; female, length, 3.24 mm.; width, 1.3 mm.

Color. Body velvety black or blackish-brown above; head dark brown along the posterior margin; pronotum with a large median rectangular yellow spot, anterior margin of spot almost as long as the width of the head, posterior margin shorter; mesonotum with a median yellow spot varying in shape from diamond to obovate lying closer to the anterior than to the posterior margin; a yellow spot lying above the acetabula on the posterior margin of the mesapleura; abdomen with a silvery bloom, caudal two-thirds of the male connexiva yellow, outer margin of female connexiva yellow for almost the entire length; entire ventral surface yellow except the anterior margin of the mesosternum, which is brown, and the middle abdominal segments, which are light brown.

Structural characters of apterous male:

Head: Distinctly longer than broad, three or four long, stiff hairs scattered along the lateral margins.

Thorax: Pronotum, length .21 mm., a stout hair directed backward from each lateral margin; mesonotum, length .75 mm., with an indistinct median line; metanotum, length .4 mm.

Antennæ: First segment the longest, almost as long as three and four together, thickened at the middle, base and apex about equal in thickness, armed at the outer under side at the middle with a brush of stiff bristles glued together, and a group of similar hairs just behind it; also a group of eight or ten stiff hairs on the dorsal side at the middle; second segment very short, half again as long as thick, a little thinner than the apex of the basal segment; the ventral base bears a tubercle armed with a brush of hairs glued together; third segment long, strongly curved at the basal third, armed at the angle with stout setæ, thickened toward the apical third which bears a pit or fossa, armed with stout setæ on the inner margin; fourth segment about one-third as long as the third, coated at the tip, not conspicuously armed.

Anterior legs: Coxæ small, trochanters enlarged and ventrally expanded, femur thinner than first segment of antennæ, armed with a row of black setæ on the ventral surface; tibiæ about one-half as long as the femora, also armed with hairs on the ventral surface; first tarsal segment very short, the two tarsal claws prominent.

Intermediate legs: Coxæ large, almost as thick as long with a tubercle on the outer posterior margin surrounded by hairs which close over it; trochanters small, only slightly thicker than femur; femur slightly over 2 mm. long and of uniform thickness throughout its length, unarmed except for a few hairs at the apex; tibiæ 2 mm. long, only very slightly sinuate, armed with short hairs along the middle; tarsi about 1.7 mm. long, the first joint about three times as long as the second.

Posterior legs: Coxæ slightly longer than coxæ of intermediate legs, but not as thick, with a small tubercle on the dorsal posterior margin; trochanter very large and globular .4 mm. thick, armed on the inner posterior margin with a broad-edged projection, the edge lying vertically; a dense row of long

hairs, arising from the inner side, extend to the median body line; femur thickened, almost as thick as the coxæ, closely and broadly joined to the trochanter without constricting, curved at about the middle toward the median body line, armed at the angle on the dorsal surface with a curious clavate structure attached at about one-third of the distance from its anterior end by means of a short stem or pedicel; femur margined on the outer side of its point of attachment to this structure by a row of stiff hairs directed upward; a brush of long stiff bristles arises from the inner apical fourth; in the natural position of the legs these brushes cross each other; tibia joined a little before the apex of the femur on the outer side, curved outward and thickened toward the apical third, then tapering to about the same thickness as the base, about as long as the trochanter and femur taken together, armed on the inner margin of the apical third of its length with a row of hairs. Tarsi a little more than half the length of the tibiæ, first segment about twice as long as second.

Structural characters of apterous female: Head slightly broader than long with two hairs on the lateral margins and one on either side of the base of the tylus, two hairs directed forward from the posterior margin of the eyes as in other species; pronotum with a hair on the lateral margin and the mesonotum with three hairs on the lateral margins; out margins of the connexiva covered with long black hairs for their entire length; anterior legs small, trochanters not expanded as in the male, femora with a row of short black setæ on the outer side and a row of fine hairs on the ventral side, two long setæ on the ventral side of the tibiæ; intermediate coxæ with a tubercle surrounded by hairs, femur straight with a row of very short black setæ on the inner margin; posterior legs straight, femora slightly thickened toward the apex, tibiæ about one-third shorter than femora, tarsi one-half as long as the tibiæ.

Notes. The male of this variety differs from that of *R. imitator* (Uhler) mainly in the following respects: The tibiæ of the intermediate legs of *R. imitator* are markedly sinuate with a short row of long hairs at about the middle with short hairs on either side of these. In variety *meinerti* var. new the tibiæ are almost straight and only the short hairs are present. The middle femora of *R. imitator* have a row of long hairs at the base and apex, while in *var. meinerti* the femora are entirely bare. In this variety the clavate structure on the hind femur projects about one-fourth of its length beyond its supporting stem, which is not the case in *R. imitator.*

The females of *R. imitator* (Uhler) and var. *meinerti* var. new can be easily distinguished from all others in the genus by the presence of the hairs on the connexiva, which are lacking in all other species. The female of var. *meinerti* has a comparatively broad dark band on the anterior margin of the mesosternum, this band is sharply broadened opposite each anterior coxa; there is also a dark band marking off the middle acetabula.

Distribution. Taken only from Aux Cayes, Haiti.

Types. Holotype, apterous male; allotype, apterous female; paratypes, three apterous males and one female. All collected by H. Nepperschmidt.

Rheumatobates trulliger Bergroth.

R. trulliger Bergroth. Bull. Brooklyn Ent. Soc., p. 63; 1915.
R. trulliger Blatchley. Hem. of Eastern U. S.; 1926.
R. trulliger Hungerford. Biology of Aquat. Hemip. North of Mexico. Kansas University Sc. Bull.; 1919.

Size. Male, length, 2.6 mm. to 2.8 mm.; width, 1 mm. to 1.1 mm.

The original description is as follows:

"Color as in *Rh. tennipes* Meinert, the pale lozenge-shaped spot on the mesonotum being narrower than the spot on the pronotum and the mesosternum being marked with two longitudinal black bands. Mesonotum of the apterous form in both sexes somewhat broader than long.

"Male: The spongy fossa of the third antennal joint occupying somewhat less than the apical half of the joint, being distinctly longer than in *Rh. rileyi* but shorter than in *tenuipes;* fourth antennal joint somewhat shorter than third, being conspicuously longer than in *R. rileyi* but a little shorter than in *R. tenuipes,* its spine placed in the basal half but nearer to the middle than to the base. Legs much as in *rileyi* but with the following differences. Middle femora perfectly straight, hairless from the base to near the apex, where there are a few hairs on the inner margin. Middle tibia fringed with long straight hairs on the inner side from the base to beyond the middle, then with short straight hairs. Curved hind femora scarcely or slightly thicker at the middle than at the base and apex, with very short and tiny hairs along the whole inner margin. Hind tibiæ on outer side between middle and apex with a distinct spine and the apex filled with a very thick tuft of rather long hairs."

Notes. In addition to the characters given above this species differs from *R. rileyi* Bergroth in having remarkably thick basal antennal segments, the vertical thickness being one-third the length of the segment; also the dorsal and lateral surfaces are free from hairs. The pronotum of the apterous form and the corresponding area of the macropterous form has short black hairs scattered over the surface resembling *R. tenuipes* Meinert in this respect. The pronotum is decidedly longer and narrower than in *R. rileyi,* but not as long as in *R. hungerfordi* Wiley. The apical third of the posterior tibia is flattened to form a spoon-shaped concavity with a dense fringe of hairs covering the margins. The spine between the middle and the apex referred to above is composed of a tuft of long hairs glued together; in many individuals these hairs have either never been joined or have become separated and no longer appear as a distinct spine, but only as a tuft of hairs somewhat longer than the adjoining ones.

Specimens taken in Arkansas are black with a bluish bloom, especially on the abdomen; the mesosternum and the spots on the pro- and mesonotum are very light yellow. Specimens taken in Kansas are light brown with the same color markings given above except that the mesonatal spot is somewhat smaller and less clearly defined.

Distribution. Georgia (type locality), Kansas and Arkansas.

Rheumatobates hungerfordi Wiley.

R. hungerfordi Wiley. Can. Ent. LV; 1923.

Description after the original:

Velvety black, covered with a bluish-white bloom except on head; pronotum with a large yellow spot occupying the entire length, quadrate to twice as long as wide with sides rounded; mesonotum with a large median yellow spot

quadrate or diamond-shaped in some species. Connexivum of male yellow for at least half its apical length, in female along outer half for almost its entire length, small yellow spot above intermediate acetabula.

Apterous Male. Structural characters: Head shorter than in *R. rileyi* Bergroth and *R. tenuipes* Meinert, slightly narrower than in *R. rileyi.* Pronotum long, longer than in any other species. Nearly twice as long as that in *R. rileyi,* but much narrower, mesonotum not as broad as long. Antennæ with the basal segment very thick armed on the outer under side with a brush of hairs glued together and just beneath with a scattered bunch of coarse hairs. Second segment short, unarmed. Third segment almost as long as first, strongly curved at basal half, large fossa or pit occupying nearly entire apical half, and extending a little beyond insertion of segment four. Segment four as long as the third with a thick tooth just before the middle, bent outward at the middle, apex curved back. Intermediate legs long and slender, femur of uniform thickness throughout, armed on inner margin with a row of long straight hairs of uniform length, base and apex bare; tibia as in *R. rileyi* with long straight hairs near the base and shorter hooked hairs at the middle, apical third bare. Posterior legs, coxa and trochanter slender, linear; femur arched as in *R. rileyi,* but not thickened, and free from hair; tibia joined to femur nearly at right angles. Angulately elbowed near the base, thickened and tufted at the angle with a stiff brush of hairs.

Notes. The macropterous form is very common. This is a very slender species resembling *R. trulliger* Bergroth in this respect.

Distribution. Recorded only from Texas and Utah.

Rheumatobates præposterus Bergroth.

R. præposterus Bergroth. Ohio Natur. VIII, p. 379; 1908.

Original description:

"*Male.* Head, pronotum and mesonotum together longer than the rest of the body; first antennal joint as long as the head, incrassated and compressed and with a submedian spine on the upper and under side, the apical part upturned with a tuft of hairs on the inner side of the tip, the upper margin almost straight from the base to beyond the middle, the lower margin angularly dilated; second joint inserted at right angles to the fore side of the apex of the first joint; third joint shorter than the first with the short basal part narrower than the second joint, straight and linear than moderately and suddenly incrassated, but not dilated and proceeding in a gentle curve to the apex, the curved apical part occupying more than two-thirds of the joint and provided on the posterior side with a very shallowly impressed spongy surface with some stiff hairs on the lower margin and a toothlike projection at the base; fourth joint a little longer than third, inserted at right angles to the back side of the apex of the third point, unarmed, shortly pilose, rectangularly curved not far from the base; fore femora very slightly thickened toward the base; middle femora as long as hind femora, slightly incrassated and curved toward the base and with a spine on the inner side not far from the apex and a very short acute spur on the same side immediately before the apex; middle tibiæ subsemicircularly curved at the base, turning the convexity of the curve outward, with a tuft of short hairs on the inner side of the tip of the curve, from which point to the apex the tibiæ are straight with some rather short straight hairs on the outer side of the middle part; hind legs straight, simple, three-fourths longer than the body, the tip of the abdomen slightly passing the base of the hind femora when they are stretched straightly backwards.

"*Female.* Head, pronotum and mesonotum together shorter than the rest of the body; antennæ simple, linear, the first joint a little shorter than the head, third joint a little longer than the first with a few rather long stiff hairs in the inner side near the base and apex, fourth joint as long as the third; fore femora linear; middle legs straight, simple femora longer than hind femora, tibiæ a little shorter than femora and longer than tarsi; hind legs as long as the body, the tip of the abdomen reaching the apical fourth of the hind femora when they are stretched straightly backwards."

Notes. The outstanding characters of this species are the peculiarly joined antennæ, the long fossa of the third joint and the arched basal portion of the middle tibia.

Distribution. Guatemala, Central America.

Rheumatobates crassifemur Esaki.

R. crassifemur Esaki. Ann. Musei. Nat. Hung. XXIII, p. 148; 1926.

Original description is as follows:

"*Apterous Form, Male.* Body black or blackish-brown. Head blackish-brown with a bluish-gray spot on the vertex. Eyes dark gray. Antennæ black with first joint yellowish-white. Pronotum black or blackish-brown with the central portion broadly yellowish-white. Mesonotum black or blackish-brown with a large bluish-gray spot at the center. Metanotum black or blackish-brown, much suffused with bluish-gray. Underside of thorax black, anterior and intermediate acetabulæ yellowish-white beneath. Anterior legs with coxa trochanter, and femur except the apex yellowish-white. Intermediate legs black or dark brown, trochanter and the base of femur pale yellow posterior legs dark brown, coxa and basal half of trochanter yellowish-white. Abdomen above black or blackish-brown suffused with bluish-gray; genital segment, apical portion of connexiva, and posterior margin of dorsal abdominal segment yellowish-white. Abdomen beneath black, with the sixth abdominal and the genital segments yellowish-white.

"Head nearly as long as broad between the eyes. Eyes moderately prominent laterally. Antennæ; first joint nearly as long as the head, much thickened at the middle, not armed with long setæ; second joint very short; third joint a little longer than the second, but thinner than the latter; fourth joint the longest, a little constricted at about one-third from the base, and vertically dilated at the apex, with a tuft of long stout setæ on the outer side at the base. Pronotum very short, comparatively much shorter than in *rileyi* or in *tenuipes*. Anterior and posterior margins moderately sinuate. Mesonotum somewhat broader than long. Metanotum about two-thirds the length of the mesonotum. Anterior legs small, trochanter about twice as long as coxa, femur not long, not incrassated, with a fringe of long hairs inwardly, though sometimes much obscured, tibia about equal to the half of femur in length, widened towards the apex; tarsus about two-thirds the length of tibia, flattened, first joint very small. Intermediate legs strongly developed; coxa very large, nearly as long as thick, with a conspicuous tubercle on the outer side near the apex; trochanter very large, a little longer than coxa; femur very long and thick, nearly as long as body, club-shaped, much incrassated near the apex, not curved, not fringed; tibia much longer than femur, about one and a half times as long as femur, much thinner than the latter, moderately tapering towards the apex, not fringed; tarsus nearly equal to half the length of tibia joint, about twice as long as second. Posterior legs comparatively short, nearly as long as intermediate tibia; coxa nearly longer than thick; coxa almost globular at the base with a conspicuous tuft of long, stout setæ at the basal corner, which is curved inwardly near the middle, connected to the femur at a little after the base of the latter; femur one and a half times as long as trochanter, incrassated towards the base, with a fringe of five or six stout

setæ on the apical half of the superior surface; tibia long and slender, about one and a half times as long as femur, not armed; tarsus very short, shorter than half the length of the tibia, first joint a little shorter than the second. Dorsal of abdomen flat, dorsal abdominal segments very distinct, connexiva conspicuous, first dorsal genital segment somewhat tubelike, a little shorter than twice the length of the sixth dorsal abdominal segment, second dorsal genital segment much shorter and narrower than the first."

Notes. The color of the female is much like that of the male, except in specimens taken in Argentina which have very little black and are a very pronounced bluish gray. The female is flat and broad, especially across the abdomen.

This species differs from *R. esakii* sp. new in having more massive appendages. The intermediate tibiæ are somewhat longer and the brush is lacking from the anterior end of the posterior femora. It occurs in both the apterous and macropterous forms.

Distribution. R. crassifemur Esaki has been taken in Argentina and Paraguay, South America.

Types. One female is in the Snow collection, Kansas University, Lawrence. Others are in Hung. Nat. Mus., Budapest, and Natur. Hist Mus., Vienna.

Rheumatobates klagei sp. new.

Apterous Form, Male. Size: Length, 2.44 mm.; width, 1.2 mm.

Color: Body dark velvety brown; head dark brown with lighter brown along the eyes; pronotum with a large rectangular lighter brown spot; mesonotum distinctly set off from the pleuræ by a black suture; intermediate acetabulæ yellow below and at the apex above; metanotum and abdomen very dark, sometimes covered with a silvery bloom, the genital and sometimes the pregenital segment yellow; basal antennal segment yellow, second segment brown, third and fourth black. Acetabulæ of the prothorax, coxæ, trochanters and basal three-fourths of anterior femora yellow; coxæ, trochanters and base of femora of intermediate legs yellow, with black areas at the apices of the coxæ and trochanters; coxæ and basal half of posterior legs yellow, remainder of leg black.

Structural characters. Head: Quadrate, as broad as long, lightly tapering anteriorly, tylus very prominent, a stout hair between the eyes and the base of the antennæ, two hairs directed forward from the posterior margin of the eyes. The beak is smooth and hairless.

Thorax: Pronotum short as in *crassifemur* Esaki, mesonotum sharply defined from the pleuræ, length and width equal (.62 mm.), metanotum a little more than half as long as the mesonotum.

Antennæ: Basal antennæ segment as long as the head including the tylus, slender, much thinner than the femur of the anterior legs, not or hardly thickened at the middle, unarmed; second segment very short, about as thick as it is long, with two fine hairs on the outer margin; third segment thinner and about one and one-half times as long as the second with two hairs on the inner margin; fourth segment as long as the first, curved outward in a regular arc, basal third thin and apical two-thirds flattened laterally, apex pointed, but not hooked, armed with a few hairs scattered around the middle of the segment.

Anterior legs: Anterior legs as in *R. crassifemur* Esaki with the apical half of the tibia expanded a little more. The ventral row of hairs on the femur extending over the basal third and apical third, the median third bare, hairs at the base very long.

Intermediate legs: Coxa large, hairy at the apex, tubercle present, trochanter comparatively longer than in *R. crassifemur* var. *esakii* var. new, also hairy at the apex. Femur not as greatly incrassated as in *R. crssifemur* Esaki and armed only with three or four stout setæ near the base. Tibia about one-fifth longer than femur, armed with a row of hairs at apex; tarsus hairy at the base, basal segment a little longer than the terminal segment.

Posterior legs: Posterior legs slightly longer than in *R. crassifemur* var. *esakii* var. new, base of trochanter thickened, but not globular as in *R. crassifemur* Esaki, the tuft of stout setæ at the upper basal corner much lighter and shorter and not bent; two tufts of setæ at the ventral base, a heavy ventral tooth a little beyond the middle. The trochanter is attached a little beyond the base of the femur; femur about one and one-half times as long as the trochanter, bowed and flattened laterally, armed with a short stout tooth on the anterior end and with a brush of long stout setæ just below the tooth directed forward to the middle of the trochanter; a comb of short stout setæ on the inner ventral edge opposite and somewhat beyond the point of attachment to the trochanter. The inner surface of the apical third is concave and has a fringe of hairs on each edge at the apex.

Description of Apterous Female. Size: Length, 3 mm.; width, 1.4 mm.

Color: Body dark brown or black with bluish bloom on the mesonotum, metanotum, pleuræ and dorsal surface of the abdomen. Head black with brown posterior and lateral margins. Pronotum with a broad median light brown spot. Connexiva black except at the apex, which is tipped with light brown. First genital segment is brownish-yellow with a black anterior margin, last segment black. First, second and basal half of third antennal segment yellow, apical half of third and fourth black. Coxæ, trochanters, femora and sometimes the base of the tibiæ of fore legs light yellow, joint between femora and tibiæ black, apical half of tibiæ and tarsi black. Coxæ, trochanters and base of femora of intermediate and posterior legs yellow, remainder black. Under side of head, prosternum and anterior half of mesosternum dark yellow with two divergent brown bands; abdomen light brown; pregenital segment yellow on the posterior margin.

Structural characters: Body much flatter than in the male, also broader and very spindle-shaped. Head less angular at the corners than in the male, antennæ slender, formula 23:8:20:30. Fourth joint slightly thickened toward the apex, four or five setæ scattered around the third segment, fourth joint with one dorsal seta at a little beyond the middle. Pronotum very short, mesonotum four times as long as the pronotum, metanotum about one-half as long as the pronotum and mesonotum together. Anterior legs as in *R. crassifemur* Esaki, but with a ventral row of long white hairs on the femur; three or four long setæ on the tibæ. Intermediate legs long and slender, coxa well developed, trochanter somewhat thicker than femur, tarsus very slender, a little more than three-fifths as long as the tibia. Posterior legs one-half as long as intermediate legs, femur as long as tibia and tarsus taken together,

tarsus less than one-half the length of the tibia, basal joint a little shorter than apical joint.

Notes. The male of this species differs from *R. crassifemur* Esaki and its variety *esakii* var. new, in being decidedly more spindle-shaped. The eyes are not as parallel, being closer together in front. All appendages are much more slender except the femora of the anterior legs, which are slightly thicker. The first segment of the antennæ, instead of being thicker than the anterior femur is hardly two-thirds as thick. The apical two-thirds of the fourth segment is almost unarmed. The length of the middle femur compared to the tibia is as 5 is to 4, much more nearly equal than the 3:2 ratio given for *R. crassifemur*. The posterior legs are longer and more slender than those of either *R. crassifemur* or its var. *esakii*. The tooth on the protruding base of the femur is greatly reduced and the brush below it is absent in both *R. crassifemur* and its variety *esakii*. The ventral tooth of the trochanter in this species is about twice as large as that of *R. crassifemur* var. *esakii*. The brush on the inner basal corner of the trochanter is also much lighter in this species; it is straight and much thinner, not meeting across the abdomen when the legs are parallel.

R. crassifemur Esaki, its variety *esakii* var. new, and *R. klagei* sp. new, form a distinct group in the genus as they have characters in common that the other species do not have. The relative lengths of the antennal segments are entirely different, as are also the segments of the posterior tarsi. In all other species the third antennal segment is at least as long as the fourth segment, while in these species the third segment is only about one-fourth as long as the fourth segment. The spongy pit of the third segment present in a fully developed form in the other species is entirely lacking in *R. crassifemur* and *R. klagei* with merely an indication of it in *R. Crassifemur* variety *esakii*.

Distribution. Taken only from the type locality on the Solimoes river, Amazonas, Brazil, South America.

Types. Holotype, male; allotype, female; paratypes, many males and females. All types are apterous. (The macropterous form is unknown.) Types deposited in the Snow collection, Kansas University, Lawrence.

Rheumatobates crassifemur var. *esakii* var. new.

Description of Apterous Male. Size: Male, length, 2.5 mm.; width, 1.2 mm.

Color: Body brown or blackish-brown, head with lighter brown along the posterior margin and the margin along the eyes; eyes black indistinctly mottled with brown; pronotum with a light brown, sometimes yellow, rectangular spot; middle actabula yellow, dorsal half sometimes black, genital segment yellow, in some species the pregenital and the connexiva of the last three abdominal segments are brownish-yellow. In the lighter species the posterior half of the ventral side of the abdomen is yellow, coxæ, trochanters and basal three-fourths of anterior legs yellow; coxæ, trochanters and base of femora of intermediate legs yellow; sometimes the coxæ are blackish-brown; coxæ and basal half of trochanters of posterior legs yellow.

Structural characters; Head: Quadrate, slightly longer than broad between the eyes, a prominent hair between the eyes and the base of the antennæ, four or five short hairs on the margin near the eyes. Two hairs extending forward from the posterior surface of the eyes.

Thorax: Pronotum comparatively short, about .2 mm. long. Width and length of mesonotum equal (.67 mm.), a distinct suture separating at least the anterior portion of the mesonotum and the mesopleura. Metanotum slightly more than half as long as the mesonotum.

Antennæ: Basal segment as long as the head, greatly thickened at the middle, much thicker than the anterior femur, unarmed. Second segment very short, as thick as it is long with two hairs on the outer side, more or less geniculately joined to the first segment. Third segment longer, but thinner than the second, with two hairs on the inner side. Fourth segment much the longest, one-third longer than the first and almost as long as the first three taken together. Basal third thin with a sharp pointed clavate spine attached laterally at the extreme base; apical third dilated vertically toward the apex, then sharply constricted into a recurved hook. Dorsal margin of dilation fringed with a row of very stout setæ decreasing in length toward the apex. Three smaller setæ near the middle of the segment. The whole segment is bowed outward.

Anterior legs: As in *R. crassifemur,* except that the femur is slightly thickened a little beyond the middle, the ventral fringe of hairs is quite sparce, broken in the middle and develops into two rows toward the apex.

Intermediate legs: Strongly developed as in *R. crassifemur,* coxa very large with a tubercle on the outer apex, trochanter much larger than the base of the femur loosely joined to the coxa. Femur club-shaped, with a row of stout short setæ along the inner margin. Tibia one-fifth longer than the femur, unarmed except for a few hairs at the apex. Tarsus hairy at the base, first segment about twice as long as the second.

Posterior legs: As in *R. crassifemur,* but somewhat longer than the intermediate tibia. Coxa twice as long a thick. A small tooth directed downward from a little beyond the middle of the ventral surface of the trochanter; trochanter articulates dorsally a little beyond the base of the femur; a comb of very short stout setæ on the inner ventral margin near the base, and a fringe of hairs on the dorsal apical third.

Notes. The general shape and appearance of this species is about the same as that of *R. crassifemur* Esaki. It differs, however, in the following manner: The middle tibia instead of being one and one-half times as long as the femur is only one and one-fifth times as long. The femur of the fore leg is somewhat thickened and the row of hair on the posterior margin is not continuous, the middle being bare. The fourth antennal segment of *crassifemur* is bowed outward regularly to the tip, while in *crassifemur* var. *csakii* var. new the tip is sharply and almost completely recurved. The fringe of long stout setæ near the apex of the fourth segment is absent in *R. crassifemur.* The description of *R. crassifemur* does not indicate the presence of the tooth on the ventral margin of the trochanter. The hind legs instead of being nearly as long as the middle tibiæ are somewhat longer.

Distribution. All specimens in the collection were taken from the Solimoes river, Amazonas Brazil.

Types. Holotype, apterous male; paratypes, three apterous males. All taken at the locality given above in association with *R. klagei* sp. new. Collected by Klages.

THE MALE GENITALIA OF *RHEUMATOBATES* AND SOME OTHER GERRIDÆ.

In recent years the genitalia have begun to play an important part in taxonomical work. At the suggestion of Doctor Hungerford that a study of the genitalia of *Rheumatobates* might be of value, especially if made a comparative one with other members of the family, the following study was made.

The so-called hemipterous orders are among the last of the more common orders of insects to receive the attention of morphologists and taxonomists in their attempt to homologize the various structures and appendages of the male genitalia.

The first substantial contribution to our knowledge of the genitalia of Hemiptera was a paper by David Sharp (*9*) on "The Structure of the Terminal Segment of the Abdomen in Some Male Hemiptera," which appeared in 1890. In this paper he described and illustrated the genital segment of numerous species of Pentatomidæ. However, as pointed out by Singh-Pruthi and other morphologists since that time, his conclusions were erroneous in several respects. He did not recognize the true interrelationship of the several parts of the ædeagus. He considered the phallosoma, which he called the "theca," as merely a protective covering of the ædeagus proper. Closer examination would have shown the two to be a continuous structure and capable of being evaginated. He credited the parameres, which he termed "lateral appendages," with being merely protective organs whose function was to serve as feelers to properly direct the ædeagus during copulation, and considered it improbable that they are clasping organs. Sharp was struck by the great differences between homologous structures, so much so in fact that it seemed incredible to him that species closely related systematically should have common ancestry.

In 1895 Peytoureau (*7*) in his paper, "Contribution a l'etude de la Morphologie de l'armure genital des Insects," gives the results of his examination of *Velia currens* (Veliidæ). He seemingly accepts Sharp's conclusions without question as he, too, considers the phallosoma as a distinct structure from the rest of the ædeagus and, like Sharp, failed to mention the basal plates at all.

In 1899 Heymans first investigated the embryological development of the genital segment.

Berlese, in 1909, was the first morphologist to study the genitalia in greater detail and was the first to describe and figure the basal

plates. Even he, however, confuses them with the parameres in certain instances.

In 1922 Christophers and Cragg (*2*) gave an excellent description of the basal plates in their paper on the genitalia of *Cimex lectularius* in referring to it as a "circumphallic chitinization encircling the base of the phallosoma and usually forming a bed for its reception . . . from this the whole organ is slung."

In the same year Raymond Poisson (*8*) investigated the chitinous structures of the ædeagus in an endeavor to determine their value as specific characters in taxonomic work. He considered the genitalia as arising from the eighth abdominal segment in which he is now generally believed to be in error. In 1924 he published his work "Contribution a l'etude des Hemipteres Aquatiques," including some of various species of *Limnotrechus, Hygrotrechus* and *Velia.*

The most important contribution to our knowledge of the genitalia of Hemiptera and Homoptera, especially the former, appeared in 1925, when Dr. Hem Singh-Pruthi released his work on "The Morphology of the Male Genitalia in *Rhynchota.*" For the first time detailed descriptions and drawings of the male genitalia of representatives of all the families and most of the subfamilies were made. However, a paper covering so large a field must necessarily be brief at some points and his treatment of the Gerroidea group is one of these. His descriptions are brief and his drawings lack the necessary detail to make them clear and comprehensive. Singh-Pruthi's work has done more to place the morphology of the male genitalia of these two orders on a firm and workable basis and to unify the terminology than has any other.

In 1926 Ekblom's (3) "Morphology and Biology of the Swedish Families of Hemiptera-Heteroptera" appeared. In this paper six families are treated. Among these are the Hydrometridæ, Veliidæ and Gerridæ. This paper is contemporary with the one by Singh-Pruthi, consequently neither one could benefit from the work of the other; there is therefore not the uniformity of terminology of homologous parts which there otherwise might have been. Parameres and copulation hooks are synonymous terms, as are basal plates and lever. Ekblom refers to the whole ædeagus as the penis and calls the endosoma the swell body. Neither one definitely names the chitinous pieces in the endosoma, merely referring to them as chitinous thickenings.

It is often quite difficult to determine the exact number of ab-

dominal segments in an insect, which in turn makes it difficult to tell with any degree of certainty from which segment the genitalia arise. It is now generally supposed that there are ten abdominal segments in Hemiptera, and that the genitalia arise from the eighth and ninth; the tenth bearing the end of the alimentary canal.

The external genitalia are composed of the ædeagus and the parameres. The ædeagus is an evagination of the intersegmental membrane of the ninth and tenth segments, or to be more exact, the ninth and tenth sternites. It is therefore a tubular structure continuous with the body wall, having numerous appendages and chitinous* thickenings, terminating in a gonopore through which the ejaculatory duct pours the seminal fluid. The attachment of the ædeagus to the abdomen is strengthened by the basal plates. This is a stirrup-shaped structure composed of two triangular chitinized sclerites which have become fused at their base. The basal portion of the ædeagus lies cradled in the basal plates when in the resting position. These plates also serve as a point of attachment for powerful muscles which assist in protracting the ædeagus during copulation. Ekblom observed a definite relation between the basal plates and the ninth sternite as they lie close together and both form a basal support for the ædeagus. When the sternite is small the basal plates are well developed and when the sternite is large the basal plates are less strongly developed.

The parameres are a pair of appendages lying on either side of the ædeagus, attached to the apices of the basal plates on their inner side and to the abdominal wall on their outer side. The size of the parameres varies greatly. In some species they are very large and may be covered with hairs. In others they are quite rudimentary and may even be entirely absent as in *Rheumatobates*. When sufficiently developed they serve as instruments to grip the female during copulation. Ekblom states that they are also used to pry open the genital valves of the female.

The ædeagus lies in a cavity or genital chamber with the basal end caudad and the distal end pointing cephalad, the basal end as stated above resting on and partly surrounded by the basal plates. During copulation the ædeagus is raised upward and backward then down and forward transcribing almost a complete circle. This is accomplished by the contraction of the muscles attached to the base

* I have used "chitinous" and "chitinized," although fully aware that "sclerotized" is recommended.

of the ædeagus and by contraction of the abdomen, causing the body fluid to exert pressure upon the organs in question. Covering and protecting the ædeagus from above is the last abdominal segment bearing the anus and forming the anal lid. In some cases the anal lid has an underflap probably formed by the tenth sternite. In the normal resting position the whole ædeagus and the parameres are protected and completely hidden from view. The only visible structures are the anal lid, its underflap when present and the ninth sternite which curves up to meet the anal lid.

The ædeagus is divided into three parts, the phallosoma, the endosoma and the conjunctiva which lies between the other two. In the resting position the phallosoma surrounds and encloses the endosoma and conjunctiva, its base is attached to the basal plates and communicates with the body cavity through the basal foramen. The phallosoma is usually somewhat barrel-shaped, open at the distal end, through which the endosoma is extruded. The degree and manner of chitinization varies to some extent. It never bears any appendages, but serves as a base and protective covering for the rest of the ædeagus.

The conjunctiva joins the phallosoma to the endosoma, being connected with the distal end of the former and the basal of the latter. In the resting position it serves as a lining between the two, and is, of course, turned inside out. It is always membranous except that either end may sometimes be slightly thickened. Like the phallosoma it never bears any appendages.

The endosoma is the distal portion of the ædeagus and is the most complicated of the three. In the resting position it lies within the other two regions, the end often protruding beyond the mouth of the phallosoma. In the larger gerrids the end is prolonged into a curious duck-bill-shaped chitinization almost as long as the endosoma itself. The endosoma contains four appendages which we shall call: (1) the median dorsal shaft, (2) the median ventral shaft, and (3) a pair of lateral plates.

The median dorsal shaft is a heavily chitinized structure lying close to the dorsal wall of the endosoma for the greater part of its length. Its shape varies greatly in the different species. Usually, however, the ends turn down and may be forked and thickened.

The median ventral shaft articulates with the anterior end of the dorsal shaft and is in some cases so completely fused as to appear continuous. Like the dorsal shaft, it also varies greatly with the

species, being broad and membranous as in some of the Gerris species, or it may be slender and heavily chitinized as in *Trepobates*. The median ventral shaft appears to carry the ejaculatory duct.

Lying close to the median lateral walls is the pair of lateral plates. These are chitinized structures sometimes having the appearance of shafts and sometimes appearing as broad plates. Their point of attachment does not seem to be constant. In most species they fasten to the posterior end of the median dorsal shaft; in certain species of Gerris they seem also to be fastened to the endosom at their other end. In *Rheumatobates* they seem to have no definite point of attachment.

In making the dissections the specimens were first cleared in caustic potash. Because of the minuteness of the genitalia they were placed in glycerin and dissected with the aid of transmitted light. The drawings were made from a lateral view after the ædeagus had been turned out of its chamber and pointed directly backward. The dorsal views were drawn slightly from the left side to prevent the overlying structures from obstructing the view of the lower.

Trepobates pictus H. Sch.

(Plate IX, Figure 4.)

Parameres well developed, tapering toward the apex which is curved upward, flattened only at the base. Basal plates not heavily chitinized except at the apices and at the point of attachment to the phallosoma where the chitinization continues as a keel almost to its mouth. Area around the mouth thickened somewhat, especially laterally. Conjunctiva with a narrow sagittate granular patch near the pallosoma, otherwise quite membranous. Endosoma also membranous except at the very end, which is somewhat thickened. Median dorsal shaft well developed, recurved at the posterior end for almost one-third its length, not thickened or expanded; anterior end furcate, branches widely separated, curved down then back. Median ventral shaft simple and chitinized, articulating with the dorsal shaft between the tips of its branches and extending anteriorly as far as the shafts, then doubling back half their length.

Metrobates sp.

(Plate X, Figures 1 and 2.)

The parameres in this species are strikingly large. In the resting position they curve up over the ædeagus, being flattened and curved toward the dorsomedial line, to give ample room for that organ, greatly dilated toward the apex. Basal plates well developed and heavily chitinized at the apices where they join the parameres. Phallosoma uniformly chitinized slightly thickened where it joins the basal plates. Conjunctiva very membranous. Endosoma membranous except for a large area on either side which is heavily chitinized

and hides the lateral plates from view. The median dorsal shaft is curiously formed in that the anterior end is trifurcate, forming two auricular structures and one median branch directly continuous with the shaft. The posterior end is curved downward, ending in a slightly recurved hook, not enlarged or expanded. Articulating with the anterior end of the dorsal shaft are two triangular plates which probably form the base of the greatly reduced ventral shaft. Lateral plates large, ovoid and thin. The ventral half is bent outward along the longitudinal axis.

Gerris Fabr.

The species of this genus examined vary remarkably. As mentioned above, the parameres are present but hardly of sufficient size to be functional. In some species, as in *G. marginatus* Say, only the lower half of the phallosoma is chitinized, the upper half being membranous. In *orba* as well as in some of the other larger species the end of the endosoma is greatly extended and expanded. The dorsal shaft is always furcate at the anterior end and usually thickened or broadened at the posterior end.

Gerris marginatus Say.

(Plate X, Figures 3 and 4.)

Parameres very short and stubby, basal plates strongly developed and heavily chitinized. The phallosoma is remarkable in that only the lower half is chitinized, the upper half being membranous, giving the region a boat-like appearance. To compensate for the lack of protection afforded by the membranous portion the upper half of the endosoma is heavily chitinized. This arrangement is unusual. The conjunctiva is membranous. The dorsal shaft is comparatively slender, furcate at the anterior end. Ventral shaft has two chitinized ribs running the whole length and is not membranous as in some members of this genus.

Gerris gillettei L. & S.

(Plate X, Figures 7 and 8.)

Dorsal shaft almost as broad as in *G. buenoi* Kirk, furcate at both ends, anterior and posterior ends quite similar in appearance. Anterior fork somewhat thicker and longer. Ventral shaft broad with the sides turned up, forming a trough, but with the posterior end thin and flattened. Lateral plates long and slender. Parameres very small. Basal plates moderately developed.

Gerris buenoi Kirk.

(Plate X, Figures 5 and 6.)

Dorsal shaft very broad, developed into a broad thick head at the posterior end. Ventral shaft articulating well up in the fork of the dorsal shaft, two ribs as in *marginata* but not so heavily chitinized. Lateral plates very broad distinctly joined to the posterior end of the dorsal shaft, much larger than in any other species examined. Parameres and basal plates as in *gillettei*.

Rheumatobates Bergroth.

The genitalia of this genus differ from the others examined in several respects. The most notable feature is the absence of the parameres. The shafts do not exist as two separate pieces, but are completely fused so that no joint is perceptible. The dorsal shaft does not extend so far caudad. The ventral shaft is long and slender and in some species terminates in a long slender coiled thread. The endosoma instead of opening on the ventral side opens at the extreme end with the coil, when present lying just outside the mouth.

Rheumatobates rileyi variety *palosi* Blatchley.

(Plate XI, Figures 1 and 2.)

Parameres absent, basal plates well developed, Phallosoma only lightly chitinized. Conjunctiva has chitinous granular thickenings where it meets the endosoma, otherwise it is very membranous. Endosoma with a chitinous thickening on either side. Dorsal shaft divided except for a short distance near the posterior end, which is dilated into two broad lamellate structures. The ventral shaft is prolonged into a coiled thread which when extended is about four times as long as the whole endosoma. Lateral plates well developed, about twice as long as wide. These plates lie in a vertical plane just outside the expanded base of the dorsal shaft.

Rheumatobates hungerfordi Wiley.

(Plate XI, Figures 3 and 4.)

Parameres absent, basal plates well developed, but not as heavily chitinized as in *rileyi*. Dorsal shaft divided as in *rileyi*. The expanded lamella of the posterior end distinctly triangular and much smaller. The coiled thread of the ventral shaft somewhat shorter. The lateral plates are ovoid and tapering toward the anterior end.

Rheumatobates trulliger Bergroth.

(Plate XI, Figures 5 and 6.)

This species is closely related to *R. rileyi* and *R. hungerfordi;* it differs from them in the shape of the expanded area of the dorsal shaft, which is sharply angled as in *hungerfordi* but not triangular and much smaller than in *rileyi*. The lateral plates are rectangular and about twice as long as broad. The coiled thread is about twice as long as in *rileyi*.

Rheumatobates klagii n. sp.

(Plate XI, Figures 7 and 8.)

Parameres absent. Lamella of the dorsal shaft very narrow and not angled. Bent cephaled dorsal shaft divided as in other species of this genus. Lateral plates greatly reduced, very narrow. The ventral shaft is not prolonged into a coiled thread. The shaft extends only to the mouth of the endosoma.

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EXPLANATION OF PLATES.

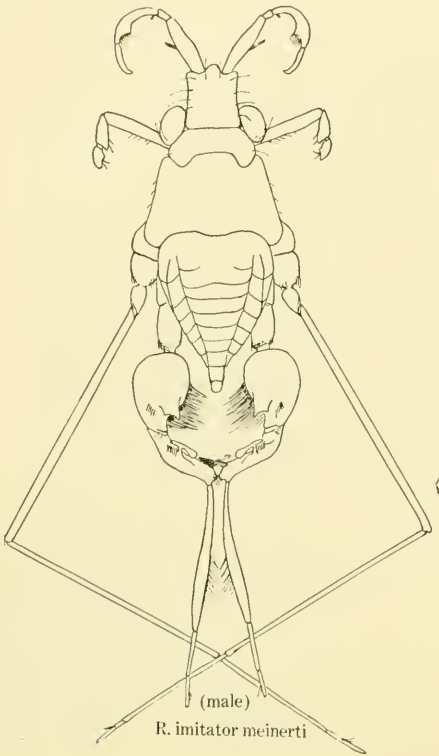
PLATE VI.

FIG. 1. *R. imitator* var. *meinerti* var. new. Male.

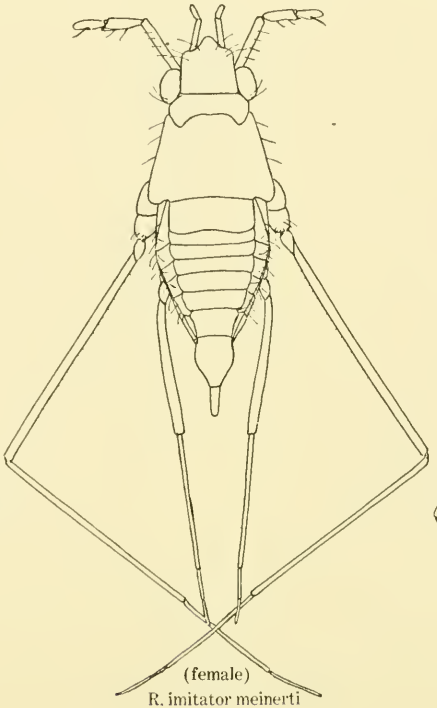
FIG. 2. *R. imitator* var. *meinerti* var. new. Female. Third and fourth antennal joints missing.

FIG. 3. *R. trulliger* Bergroth. Male.

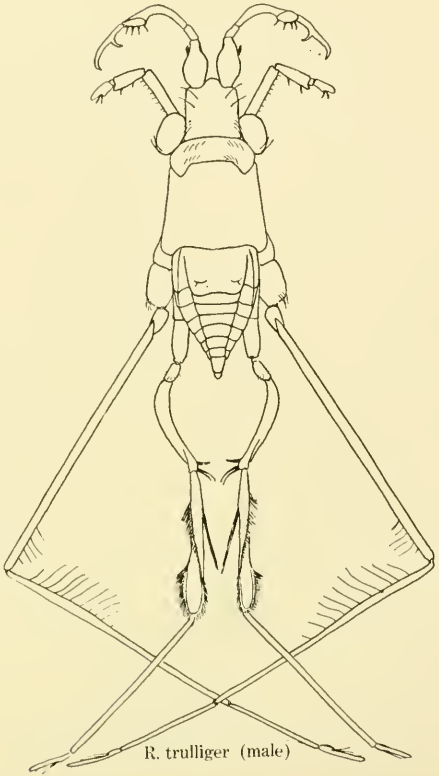
PLATE VI.



(male)
R. imitator meinerti



(female)
R. imitator meinerti

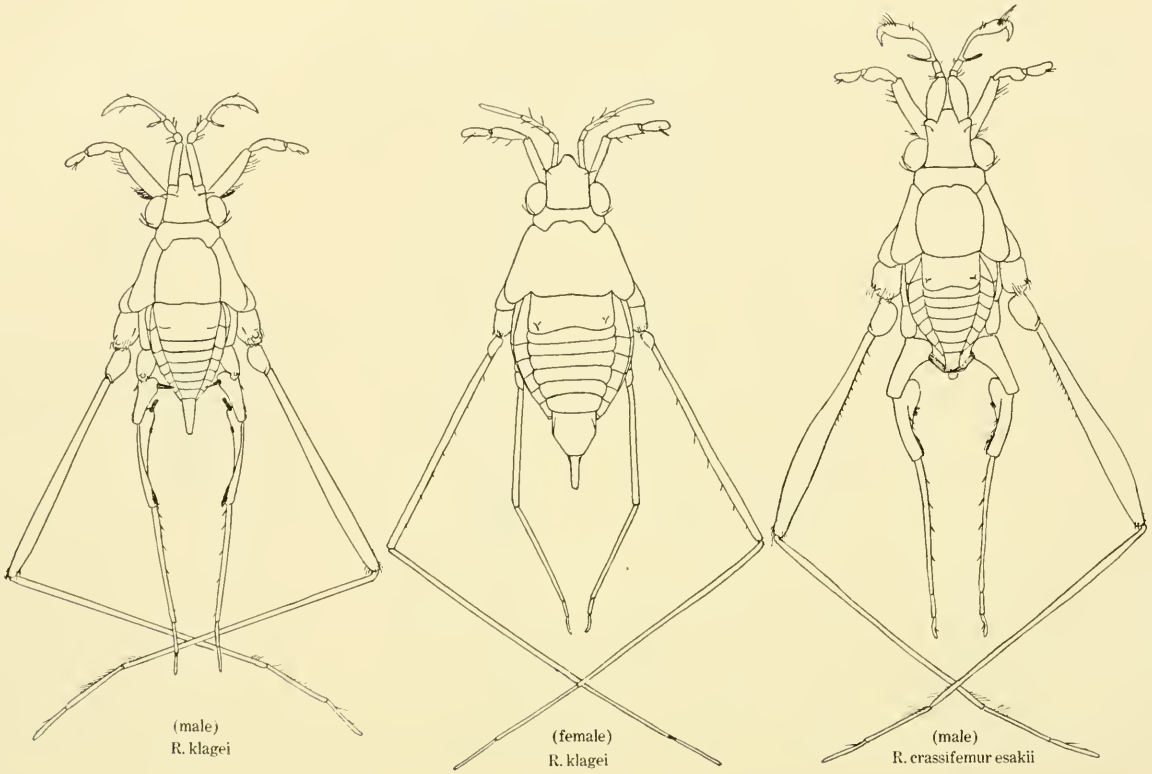


R. trulliger (male)

PLATE VII.

FIG. 1. *R. klagei* sp. new. Male.
FIG. 2. *R. klagei* sp. new. Female.
FIG. 3. *R. crassifemur* var. *esakii* var. new. Male.

PLATE VII.



(male)
R. klagei

(female)
R. klagei

(male)
R. crassifemur esakii

PLATE VIII.

FIG. 1. Trochanter and femur of right posterior leg of *R. imitator* var. *meinerti* var. new. Male.

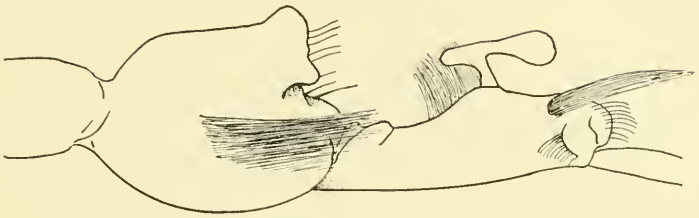
FIG. 2. Trochanter and femur of right posterior leg of *R. klagei* sp. new. Male.

FIG. 3. Trochanter and femur of right posterior leg of *R. crassifemur* var. *esakii* var. new. Male.

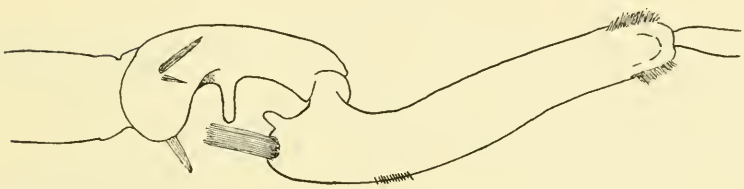
FIG. 4. Right antenna of *R. crassifemur* var. *esakii* var. new. Male.

FIG. 5. Left antenna of *R. klagei* sp. new. Male.

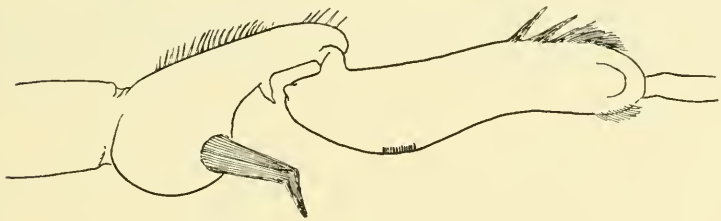
PLATE VIII.



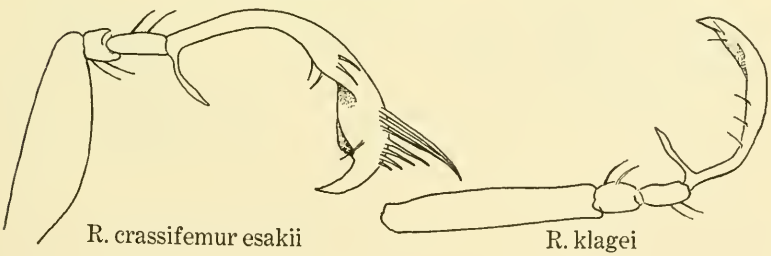
R. imitator meinerti



R. klagei



R. crassifemur esakii



R. crassifemur esakii R. klagei

PLATE IX.

FIG. 1. *Gerris remigis* Say. The endosoma has been removed from the phallosoma and the shafts and lateral plates are somewhat extruded. In the normal position these structures are completely inclosed by the endosoma.

FIG. 2. Dorsal view of shafts and plates of *Gerris remigis* Say.

FIG. 3. Dorsal view of the curiously expanded tip of the endosoma.

FIG. 4. The genitalia of *Trepobates pictus* H. Sch. In the normal position the endosoma lies within the phallosoma and the whole swings forward, resting between the parameres covered by the tenth tergite.

FIG. 5. Dorsal view of shafts and plates of *T. pictus*. IX, Ninth segment of the abdomen. *X*, Tenth segment of the abdomen. *bp.*, Basal plates or lever. *pr.*, Parameres. *ph.*, Phallosoma. *cj.*, Conjunctiva. *end.*, Endosoma. *ejd.*, Ejaculatory duct. *ds.*, Dorsal shaft. *vs.*, Ventral shaft. *lp.*, Lateral plates.

PLATE IX.

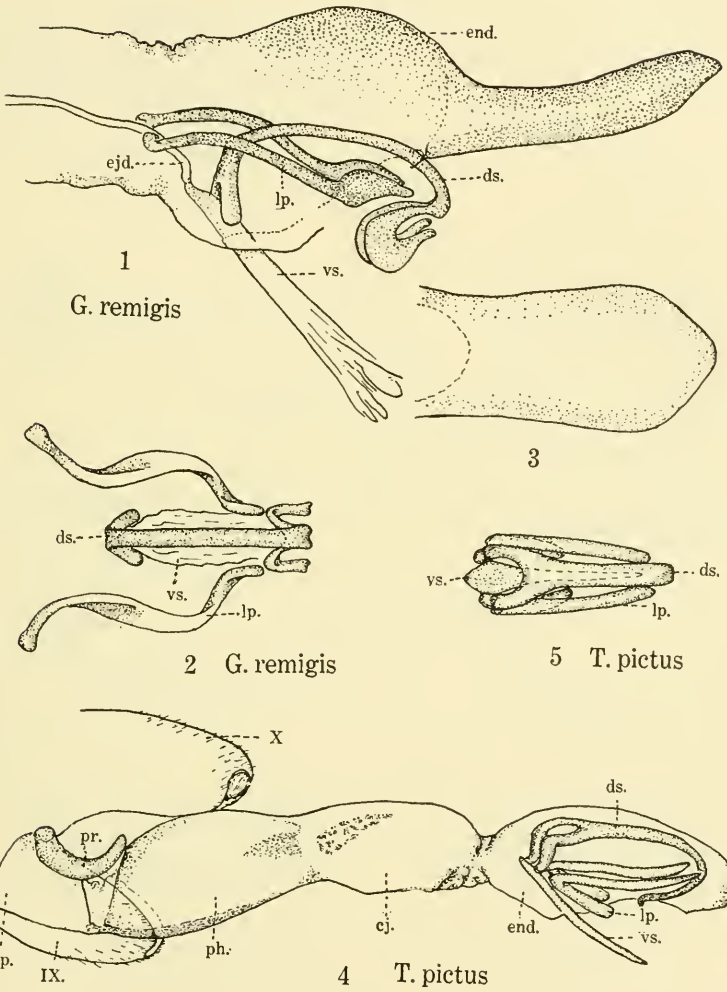
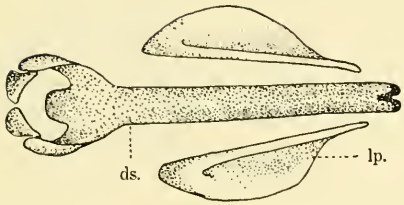

end.
ejd.
lp.
ds.
vs.
1
G. remigis
3
ds.
vs.
lp.
2 G. remigis
vs.
ds.
lp.
5 T. pictus
X
pr.
ds.
lp.
vs.
cj.
end.
bp.
IX.
ph.
4 T. pictus

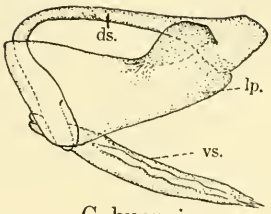
PLATE X.

FIGS. 1 and 2. *Metrobates* sp.
FIGS. 3 and 4. *Gerris marginatus* Say.
FIGS. 5 and 6. *Gerris buenoi* Kirkaldy.
FIGS. 7 and 8. *Gerris gillettei* L. and S. *ds,* Dorsal shaft. *vs,* Ventral shaft. *lp.,* Lateral plates.

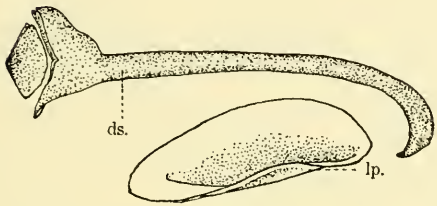
PLATE X.



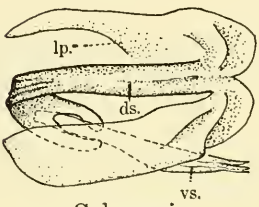
Metrobates sp.



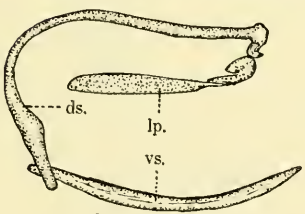
G. buenoi



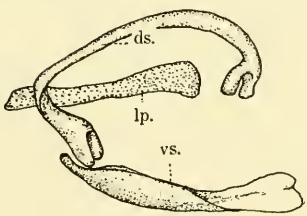
Metrobates sp.



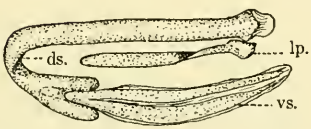
G. buenoi



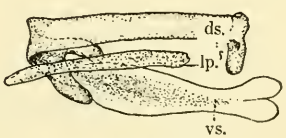
G. marginatus



G. gillettei



G. marginatus

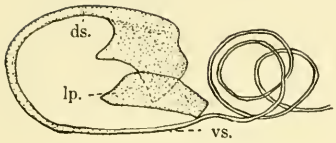


G. gillettei

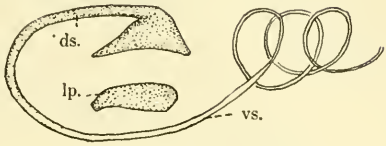
PLATE XI.

FIGS. 1 and 2. *Rheumatobates rileyi* var. *palosi* Blatchley.
FIGS. 3 and 4. *Rheumatobates hungerfordi* Wiley.
FIGS. 5 and 6. *Rheumatobates trulliger* Bergroth.
FIGS 7 and 8. *Rheumatobates klagei* sp. new. *ds.*, Dorsal shaft. *vs.*, Ventral shaft. *lp.*, Lateral plates.

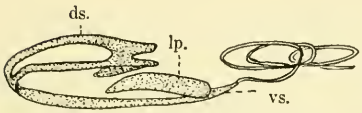
PLATE XI.



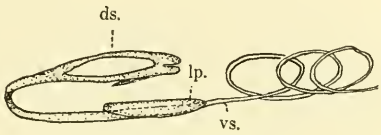
1 R. rileyi palosi



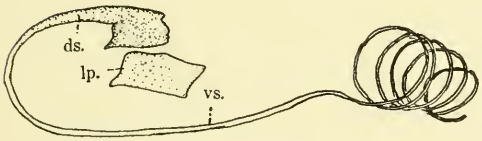
3 R. hungerfordi



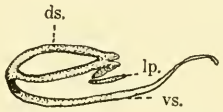
2 R. rileyi palosi



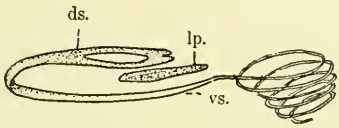
4 R. hungerfordi



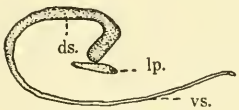
5 R. trulliger



7 R. klagei



6 R. trulliger



8 R. klagei

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SCIENCE BULLETIN

VOL. XX.] MAY 15, 1931. [No. 3.

Anaphylaxis: XIII. Studies on Mechanism of the Reaction.

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IN previous papers by Sherwood, and Downs (*1*), Downs (*2*), Goodner (*3*), and Sherwood (*4*), it has been shown that sensitized turtles, frogs, and a small percentage of passively sensitized chick embryos respond to a shocking dose of antigen by cardiac slowing and stopping frequently in diastole. Since it was possible to demonstrate sensitization in only a small per cent of 48- to 96-hour chick embryos, it was thought desirable to study several hundred chick embryos histologically and pharmacologically.

The results of the present studies in the embryonic cardiac mechanism may be summarized as follows:

1. Histological studies of embryos varying in age from 48 to 96 hours failed to reveal evidence of a nervous mechanism. This is in harmony with the work of previous workers.

2. Diphtheria toxin which Burrows and Suzuki found toxic for heart muscle of older chick embryos was without effect on the hearts of 48-, 72- and 96-hour-old embryos.

3. Caffein citrate in doses of 1 to 6 mg. per 20 cc. of bath gave negative results, as did also small doses of ergotoxin and adrenalin.

4. Barium chloride, ether and chloroform slowed the embryonic chick heart.

5. Atropine sulphate in large doses seemed to cause irregularity in a few embryonic hearts.

6. Likewise, with pilocarpine a few hearts became irregular but were restored to normal rhythm with a change in bath. It might be added that these results were obtained at temperatures of 26 degrees centigrade as well as higher temperatures, *i. e.*, 39 degrees centigrade and under.

7. Physostigmin appeared to have a definite mild slowing effect upon a few embryonic hearts of 72- and 96-hour-old embryos.

8. A study of the effect of varying the potassium-calcium ratio of the bath showed that when the potassium ratio was increased four to five times over the ratio in Lock-Lewis solution, that a marked slowing of the embryonic heart occurred with long pauses or complete stopping in diastole. This phenomenon is similar to the anaphylactic cardiac response of the frog, turtle, embryonic chick heart and that which Auer has reported for the rabbit. Sollman has called attention to the stimulation of a parasympathetic mechanism by this method.

9. These results suggest that the embryonic heart of a few 72-hour-old embryos is apparently mildly responsive to physostigmin and perhaps to atropine and pilocarpine. It suggests that functional properties of a nervous mechanism can be demonstrated in a small per cent of embryos two or three days before histological studies demonstrate it or else the heart muscle of a few embryos possesses this property. It is interesting to note that the percentage so stimulated corresponds to the percentage showing sensitization.

10. It might be added that studies on the sensitized uterine horns of virgin guinea pigs carried out in hypotonic and isotonic sugar solutions in distilled water, tended to support this hypothesis. The results, however, are open to other explanations.

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THE UNIVERSITY OF KANSAS
SCIENCE BULLETIN

VOL. XX.] MAY 15, 1931. [No. 4.

Anaphylaxis: XV. A Theory as to Its Mechanism.

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THE historical development of our knowledge of anaphylaxis and a critical discussion of theories advanced up to a few years ago have been published by Wells (*1*), Coca (*2*), Zinsser (*3*), and more recently by Karsner (*4*).

At the present time we find the old theories still persisting and that some newer concepts have been advanced. These may be summarized to a large extent briefly as follows:

1. Vaughn's (*5*) split product theory which assumes that following the initial injection, enzymes are built up that quickly split the protein used for the shocking dose into a toxic and nontoxic fraction; the former giving rise to the manifestations of shock.

2. The anaphylatoxin theory of Friedman (*6*) and also Friedberger (*7*), whose test-tube experiments led them to assume that complement plays a rôle in the development of a specific toxic substance.

3. The anaphylatoxin theory of Manwaring (*8*). He thinks he has shown that a toxic substance is formed in the liver and explosively liberated. He also thinks he has shown that permeability change is a factor. Simonds (*9*) has offered a different explanation for the hepatic phenomena.

4. Nicolle's (*10*) anaphylactic poison theory based upon Bordet's two-phase reaction and perhaps the participation of complement.

5. The histamine theory which is advocated by Abel and Kubota (*11*), Dale and others. Dale (*12*) has pointed out the objections to an enzyme explanation, but has not explained how else histamine could be formed to produce anaphylaxis. Karsner (*4*) had more recently pointed out other discrepancies.

6. The protease theory of Jobling, Peterson and Eggstein (*13*) in which it is assumed that the "intoxication is brought about by

the cleavage of serum proteins through the peptone stage by a non-specific protease" and that "the specific element lies in a rapid mobilization of this ferment and the colloidal serum changes which bring about the change in antiferment titer."

7. The mechanical irritation theory apparently held by Weil, Coca (*2*) and others assumes that the formation of a precipitate in or on the tissue cells produces the symptom complex of anaphylaxis.

8. The anaphylactic inflammation theory of Opie (*14*) assumes that an inflammatory process is initiated when antigen meets antibody in or on the tissue cells.

9. The colloidal dispersion theories (*4*) which have been held by Kritschensky (*15*), Doerr and Moldovan (*16*) and apparently to some extent by Novy, DeKruif and others assume that a change in dispersion occurs and is either directly or indirectly the cause.

10. A nervous mechanism theory (*4*) suggested by Gay and Southard (*17*) and supported by Besredka and others. Pottenger (*18*) and others assume that the phenomena of anaphylaxis is due to a stimulation of the parasympathetic nervous system.

11. The theory which one of us offered at the joint meeting of the pathologists, bacteriologists and immunologists at Chicago in 1929. This assumes that in the antigen-antibody reaction a disturbance of the electrolyte balance occurs in or on the surface of the cells and is the spark that initiates the chain of phenomena observed in anaphylaxis. The disturbance of the potassium-calcium ratio and the chronaxie changes being, perhaps, the most outstanding factors as a rule and would explain the commonly observed parasympathetic stimulation.

Assuming that it is well established that experimental anaphylaxis is due to an antigen-antibody reaction and that Wells' (*1*) criteria have been fulfilled, it would seem desirable to know, if possible, just how the antigen-antibody combination produces the physiological response.

It would seem that any satisfactory theory should account for the following:

(*a*) The varied symptoms of acute shock in different animals, *i.e.*, the asphyxia in the guinea pig, cardiac failure in the rabbit, drop in blood pressure in the dog, cardiac slowing in the turtle, frog and embryonic chick heart.

(*b*) The response of the isolated uterine horn and intestinal loop of the guinea pig and of isolated heart of the frog.

(*c*) The characteristic response of the urinary bladder of dogs and the crop reaction in the pigeon.

(*d*) The arthus phenomenon.

(*e*) The phenomenon of desensitization or the refractory state.

While the first six theories radically differ in many respects, they are all apparently dependent on enzyme or cleavage action forming a toxic substance responsible for the phenomena of anaphylaxis. Dale dissents from the enzyme theory while still holding to the histamine hypothesis.

In favor of these theories considerable evidence has been offered. The anaphylactic response can apparently be imitated by histamine and peptone. Karsner (*4*) has recently summarized serious objections to both. Wells, (*1*) (1921) has outlined the evidence against the humoral theory as follows:

"It does not fit the latent period of passive sensitization. Intracellular formation of anaphylatoxin might account for this, however.

"2. Complement is not essential since animals deprived of complement in the circulating blood may still give anaphylactic reactions. Here again one may suggest intracellular or reserve complement.

"3. All attempts to prove that complement is a proteolytic ferment have failed.

"4. Anaphylatoxin activity has been produced in serum by digestion in the absence of complement, in the absence of antigen and in the absence of antibody. On the other hand, if antigen and the specific antibody are injected simultaneously into the opposite jugular vein of a guinea pig the animal shows no evidence of intoxication.

"5. In the anaphylatoxin experiments the existence of capillary embolism or endothelial intoxication has not been excluded and there is reason to believe that most of the observed symptoms are anaphylactoid."

Dale has pointed out the difficulty of harmonizing the time interval of the smooth muscle reaction with any enzyme theory. When one repeatedly observes the time interval for the onset of acute shock in the guinea pig, dog and rabbit and notes that frequently it is from one to three minutes following intracardiac injections, or the drop in blood pressure in the anæsthesized dog which very frequently starts in fifteen to forty-five seconds after the intravenous injection of the antigen, he is forced to doubt the enzyme theory, alluring as it is. These doubts are greatly augmented, as Dale has pointed out, when one works with sensitized uterine horns and notes that the time interval between adding the antigen to the bath and response is commonly one minute. When one realizes that in both injection experiments and in the smooth muscle work a large part

of the time interval is taken up in the antigen reaching the tissues, one is impressed with the fact that whatever the mechanism may be, it can, even though it does not always, be brought into action very quickly. Our general experience with enzymes is that there is a comparatively much longer period of time required for action than occurs here. The isolated uterine horn reaction is difficult to harmonize with any theory requiring the production of a toxic substance elsewhere in the body, and for that matter in the horn itself. It has a cellular and intrinsic nervous mechanism but practically no circulation since it has been perfused, removed and suspended in a bath.

Since there seems to be quite a wide acceptance of either the histamine theory or peptone hypothesis, we had Bally (*19*) carefully study the comparative physiological response in the rabbit following the injection of histamine and peptone and in the sensitized rabbit of antigen. In other words, he compared true anaphylactic response with the response to histamine and peptone and found that anaphylactic response, while more like that of peptone than to histamine, yet was really unique in having a characteristic picture of its own. His work suggests that in peptone shock, and to some extent in histamine shock, the same mechanisms are more or less involved as in anaphylaxis. Other objections to either histamine or peptone being responsible for anaphylactic shock have been recently summarized by Karsner (*4*).

For reasons mentioned above it seems desirable to mention again briefly the physical theories offered. The mechanical irritation theory assumes the identity of precipitin and sensitizer and a mechanical concept of eliciting a response. Stoland and I have considerable data that supports Manwaring's conclusion and those of Falk and Caulfied and others (4) that serum rich in sensitizer may be of no value in precipitin work. The colloidal dispersion theories may contain some concepts of importance and need not necessarily be in disagreement with Opie's inflammation theory, or, for that matter, with any theory that includes the participation of the vegetative nervous system.

Opie (*14*) is the only one who has attempted to make a theory of anaphylaxis explain the Arthus phenomenon. His theory has much to commend it.

Recently we (*20*) have shown that when horse serum is injected into dogs there results very early an increase in the irritability of muscle-nerve as determined in studies on the vagi. While we think we have shown that this is independent of anaphylaxis, as we in-

terpret it, yet it is conceivable that it may play a rôle in acute shock. It is of interest especially in view of some studies carried out by us on the disturbance of electrolyte balance in guinea pigs, rabbits, dogs, and suspended sensitized uterine horns. It is of further interest in view of the work of Northrop and DeKruif (*21*) and Mudd (*22*), and in our laboratory of Downs and Gottlieb (*23*) on the rôle of electrolytes in certain immunological experiments in vitro. It might be added here that Pottenger (*18*), from his clinical experience, has long felt that the parasympathetic mechanism was the one stimulated in hypersensitive reactions.

Kuscharjew (*24*) has recently reviewed the literature dealing with the rôle of the vegetative nervous system in experimental anaphylaxis and its stimulation by the alteration of potassium-calcium ratio. He concludes that in anaphylactic shock there is an increase in blood potassium and a decrease in blood calcium. Our own work and that of others has led us to formulate the following working hypothesis of what occurs in a sensitized animal as the initiative factor in acute anaphylactic shock. In the first place, we feel that the so-called two-phase reaction of Bordet has much to commend it, and that there is a very high degree of analogy between it and our theory of the mechanism of anaphylaxis. It might be noted here that this differs from Nicolle's (*10*) anaphylatoxin theory in that we think the physiological, physical and physicochemical changes are the logical sequelæ and also the most important physiological phenomena.

Our conception is that when an animal receives an initial dose of protein it physiologically produces antibodies which are at first found in great abundance in the blood stream and then disappear from the blood stream and are found associated with the tissues of the body. This concept is not original with us and has fairly wide acceptance. We feel that the antibodies are in combination with the cells at their surfaces enjoying perhaps an unequal distribution in the body but definitely present in the smooth muscle tissues. We (*20*) have shown for horse serum, at least in dogs, that the injection of horse serum causes, as a rule, an increase of irritability of muscle nerve as determined by chronaxie studies. Now when there is injected into the blood stream of this sensitized animal a shocking dose of antigen, the antigen unites with the antibody at or on the surfaces of the cells, and in accordance with Bordet's two-phase reaction and the work of Northrop, Mudd, Downs and Gottlieb there would probably occur a disturbance of electrolyte balance around the cell.

Since calcium is a divalent ion it would have what has been estimated to be a 100-1 chance of entering into the reaction over the monovalent ions sodium or potassium. This would disturb the calcium-potassium ratio. Sollmann (*25*) and others have called attention to the fact that the parasympathetic mechanism is very sensitive to a disturbance of the calcium-potassium ratio and is readily stimulated by the increasing ratio of potassium to calcium. If there is an increase in irritability resulting from the primary injection of the protein, it might make it possible for a smaller change in the ratio to bring about physiological response than normally. In this connection we hope to study chronaxie changes in passively sensitized animals more extensively to ascertain whether the process of adsorbing antibodies affects irritability, and also whether the injection of purified proteins will produce a similar change, as indicated by Manwaring's perfusion experiments. We feel that perhaps this disturbance of electrolyte balance may be the spark that initiates the chain of symptoms which we recognize as anaphylactic shock.

According to this theory the site of electrolyte disturbance would be only in those tissues or fluids where antibody was present. It seems logical to assume that the optimum conditions for immediate cellular effects would be when the circulation was low in titer or free of antibody and when the latter was in physical or physicochemical combination with the cells at their surfaces. Only those tissue cells that had adsorbed or contained antibody would be affected. This would explain the impossibility of exactly imitating an electrolyte disturbance by injecting electrolytes into the general circulation. Especially is this true for potassium chloride, which is so extremely toxic for heart muscle. This would also explain desensitization or the refractory state, since when the antibodies are in physicochemical union with antigen a second injection of antigen will not lead to an antigen-antibody reaction and hence no electrolyte disturbance. When dissociation of antigen from antibody occurs, sensitization would recur. Or if antibody would be dissociated from tissue cells the refractory state would be lasting.

This theory would also account for some sensitized animals not reacting or not giving classical symptoms or the uterine horns not reacting. This might be explained by one or more of the following alternatives: 1. The horns might not contain antibody. 2. Other electrolytes than calcium might enter the reaction, giving changes not observed and not due to parasympathetic stimulation. 3. An inhibitory mechanism might be independently or simultaneously

stimulated. This latter phenomenon we (*26*) have reported in a previous communication. 4. The chronaxie change might still indicate a relatively low irritability, since animals vary a great deal in normal parasympathetic irritability. Even though calcium does enter, there is a quantitative factor in regard to the potassium-calcium ratio that perhaps must be satisfied to get parasympathetic response. Our experimental work has suggested such. Judging from the work of Loeb (*27*), Donnan (*28*) and others (*29*) this surface disturbance of the electrolyte balance and chronaxie change would account for all shades of increased permeability which have been reported. It should, however, be remembered that a vast amount of permeability change might well be secondary, as, for example, the engorgement and slowing down of the circulation in the liver and splanchnics. This theory might also explain the response of excised uterine horns and the cardiac response, perhaps the early changes which Opie considers inflammatory reaction. The Arthus phenomena could well be an inflammatory reaction developing in the manner which Opie has outlined in his splendid paper. The anaphylactic response to heterophile antigens might also be mediated by this mechanism. It might be added that Bordet's experiments on the rôle of electrolytes in the agglutination reaction lends some support to this theory by analogy.

The evidence which has been accumulated that seems to point to an intrinsic nervous mechanism (usually parasympathetic) stimulation as responsible for at least a large part of the visible phenomena of anaphylaxis may be summarized as follows:

Observations by Auer (*30*) and others that atropin frequently modifies or prevents the acute reaction in guinea pigs. Atropin is known to produce a "block" or chronaxie change of the parasympathetics. Adrenalin also protects, supposedly by stimulating the antagonists of the parasympathetics. Stoland and Sherwood (*31*) have shown that atropin also prevents the specific uterine horn reaction. Robinson, Auer (*32*) and others have shown that heart block also occurs in rabbits and dogs. The work of Sherwood and Downs (*33*) and of Downs (*34*) on anaphylaxis in turtles has shown that cardiac slowing is the outstanding phenomenon. Goodner (*35*), working in our laboratories, has also shown that the same is true for anaphylactic response in the isolated frog heart, and that the small intestine of frogs which Roth describes as not having parasympathetic innervation did not respond. Sherwood (*36*), working with

48- to 72-hour embryonic chicks, showed that while most could not be passively sensitized using immune serum from chickens, yet a small percentage could be definitely shown to be rendered specifically sensitive. The reaction consisted of cardiac slowing or stopping in diastole. While these embryos show no histological evidence of a nervous mechanism, it is of interest to note that Sherwood, Davis and Schwegler (*37*) have shown that approximately the same percentage are affected by physostigmin, atropin and pilocarpin. Pearce and Isenbrey (*38*), in their classical studies on canine anaphylaxis, ruled out the central nervous system but could not rule out the intrinsic nervous mechanism of the liver. Their results suggested that it was the factor stimulated, for they say that "pharmacological experiments point to an influence on the nerve endings rather than to one on the muscle of the vessels." In Auer's (*39*) degeneration experiments the vagi were allowed to degenerate and thus apparently ruled out as necessary in the reaction, but it is obvious that this would probably leave intact the intrinsic nervous mechanism of the lungs. Bally's "ear reaction" in anaphylactic response in the rabbit suggests that stimulation of the Rouget cells of the capillaries. The work of Zondek (*40*) suggests the rôle of calcium and potassium in the stimulation of the vegetative nervous system and the effect of the stimulation of the latter on the blood calcium and potassium. More recently the work of Kuschnarjew, previously referred to, strongly points to the frequent involvement of the parasympathetics in anaphylactic shock.

In an endeavor to obtain more data along these lines we have attempted to answer the following questions by experiments:

1. Will injections of potassium salts produce any of the symptoms of anaphylaxis in the guinea pig, rabbit and dog?

2. Will the disturbance of the electrolyte balance by injection of calcium or potassium have any effect on the anaphylactic response in sensitized animals?

3. Will disturbance of the electrolyte balance affect the cardiac mechanism of the embryonic chick simulating the anaphylactic response?

4. What would be the effect on the uterine horn of virgin guinea pigs of varying qualitatively and quantitatively the electrolyte content of the bath?

5. What would be the effect on sensitized uterine horns of reduc-

ing their electrolyte content by suspending them in varying concentrations of sugar solution made up in distilled water?

6. What would be the effect on the precipitin titer of antigen introduced into the sugar bath in which normal uterine horns were suspended as compared with sugar bath in which sensitized horns were suspended?

EXPERIMENTAL METHODS AND RESULTS.

Molecular solutions of KCl and $CaCl_2$ were made up and used separately and in combination for both intracardiac and intraperitoneal injections in laboratory animals. For uterine horn work all solutions were made up so that .5 cc. contained the amount of the electrolyte normally contained in 25 cc. of Tyrodes solution.

From the injection experiments it was apparent that lethal injections of KCl into guinea pigs produced cardiac failure and asphyxia with the lungs extremely distended with air. They would not collapse on opening the chest. In a few instances mild symptoms such as sneezing and scratching were produced with recovery. In a few instances there was a delayed clotting time of the blood.

In rabbits cardiac failure was a common picture in all but a few instances where exopthalmus and head retraction occurred.

In dogs, following injections into the jugular vein, cardiac failure occurred with relatively small doses of KCl. In a few instances there was a prolongation of the clotting time of the blood. Injections into the portal vein appeared to be relatively nontoxic.

In sensitized guinea pigs that were injected with either calcium or potassium salts intraperitoneally before the shocking dose of specific protein was administered the following was observed:

(*a*) The work of others was confirmed that calcium frequently has some protective value.

(*b*) The injection of 1.3 cc. of M/1 KCl intraperitoneally, anywhere from two to twenty minutes before the intracardiac injection of the shocking dose of antigen did not shorten or lengthen the time of death, but did apparently modify the pulmonary distension by lessening or preventing it.

In regard to the embryonic chick heart, the increasing of the potassium ratio produced anaphylacticlike symptoms. This was also true in the uterine horn work.

When isotonic glucose (5.7 per cent) was substituted for Tyrode's solution in the uterine horn bath the horns contracted apparently

to their maximum. By reducing this to 4 or 4.5 per cent a reasonable amount of relaxation occurred and the horns would remain viable for a long time. Sensitized horns would not give a visible response when antigen was added, but became desensitized or else the antibodies had become dissociated as a result of being in the sugar solution. In one instance a mild, specific response was obtained sixteen and one-half minutes after the horns had been washed repeatedly, first in sugar solution then in Tyrode's solution. The horns were found viable but were, with the one exception, desensitized.

In regard to the effect of normal and sensitized uterine horns on the antigenic content of the bath, it was noted that when normal horns were suspended no change occurred, as a rule, but when sensitized horns were suspended the titer of the antigen in the sugar bath would drop quite noticeably, *i. e.*, it might drop from 5,500 to 3,300.

While the results of the experimental work are decidedly inconclusive they seem to lend some support to the theory we have outlined. We have some data which suggest that here, as in peptone shock, the mechanism for prolongation of clotting time is perhaps somewhat different from the one causing the drop in blood pressure in the dog. This theory which we have just presented is offered merely as a working hypothesis in hopes of throwing more light on the phenomena, both clinical and experimental, that may fall in the scope of anaphylaxis.

SUMMARY AND CONCLUSIONS.

We have called attention to eleven theories that attempt to explain the phenomena of anaphylaxis, and have outlined criteria which it seems to us should be satisfied.

In addition we have brought together the evidence from the literature and from our own experiments which led us to offer in 1929 the following theory as to the mechanism initiating the anaphylactic reaction.

This assumes that a disturbance of electrolyte balance in or on the surface of the cells occurs when antigen meets antibody that has been adsorbed by the cells. This disturbance is the spark that initiates the chain of phenomena observed in anaphylaxis. Since calcium is a divalent ion, the probability of it entering the colloidal reaction rather than potassium or sodium would be approximately 100 to 1. This would result in a disturbance, as a rule, of the potassium-calcium ratio. We believe that the above changes affect the

parasympathetics and organs innervated by these nerves to a greater extent than they affect other tissues. The permeability changes, refractory state, and other phenomena can in this manner be accounted for. We furthermore include as additional factors which would make more effective this mechanism the increased irritability which our chronaxie studies and Manwarning' perfusion experiments suggest, together with evidence pointing to the intrinsic nervous mechanism of various organs bearing the brunt of the attack, as maintained by Pearce and Isenbrey.

Attention is called to Bordet's experimental work on the rôle of electrolytes in agglutination as affording support by analogy to this theory of electrolyte disturbance.

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On a Seed-bearing *Annularia* and on *Annularia* Foliage.

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1. Prior to naturalization a citizen of the United States, M. K. Eliashevich, of Russia.

ABSTRACT.

SEEDLIKE fruits in direct connection with *Annularia* foliage comparable to *Annularia westphalica* Stur and *A. geinitzi* Stur are described on specimens from Lower Pennsylvanian beds near Clinton, Mo. Anatomy of the common types of *Annularia* leaves from North America, Europe and Siberia is reviewed and compared. Most Pennsylvanian leaves of North America and Europe which are customarily classified with *A. stellata* Schlotheim do not belong to this species, which is not identical with *A. westphalica* and *A. geinitzi.* Typical *Annularia* leaves are recognized in the controversial flora of the Kuznetsk Basin, Siberia, which is now proved to be a mixture of floras of two different ages: Upper Paleozoic and Jurassic. In particular, the Paleozoic *Annularia* leaves have been mixed with Jurassic *Pityophyllum* leaves, the two being erroneously supposed to represent a foliage of one species which was referred to *Cyclopitys* (Schmalhausen) or *Phyllotheca* (Zalessky).

The new genus and species *Carpannularia americana* from Lower Pennsylvanian of Missouri and the new species *Annularia zalesskii* from the Upper Paleozoic of Siberia are described and figured.

Annularia foliage with recognizable minute structure is classified in three groups, that are possibly of generic rank: (1) Group of *Annularia stellata,* (2) group of *Annularia westphalica,* and (3) group of *Annularia zalesskii.*

INTRODUCTION.

During the study of some extinct floras of Siberia the writer found it necessary to make a comparative study of the minute structure of the *Annularia* leaves from the North Atlantic botanical province of Upper Paleozoic age. The difficulty with the Siberian plant remains, which belong to *Annularia*, arose from the unfortunate mix-up of these (and other) Paleozoic remains from Kuznetsk Basin[2] with the somewhat similar forms from the Jurassic of the same area, the two kinds being erroneously supposed to come from the same formation.[3] Schmalhausen (*19,* pp. 39-42; *20,* pp. 151-156) thought that all *Annularia*-like remains of Kuznetsk Basin belong to a new and peculiar extinct conifer which he named *Cyclopitys* and believed to be of Jurassic age. Zeiller (*36,* p. 476; *37,* pp. 887-888) criticized this view and compared the whole Jurassic

2. Kuznetsk Basin is located in south-central Siberia between 85-88 degrees east longitude and 53-56 degrees north latitude.

3. For modern data and discussions on this subject see (2), pp. 63-68; (3), footnotes to pp. 304-305; (5), pp. 55-63; (14), pp. 337-342; (15), pp. 303-305; (29), p. 7.

and Paleozoic lot with *Annularia,* an opinion at one time shared by Zalessky (*34,* p. 28, footnote). Later, however, the latter author referred the *Cyclopitys* leaves of Schmalhausen to *Phyllotheca stschurowskii* Schmalhausen and considered both to belong to the same species of *Phyllotheca* (*35*). Both Zeiller and Zalessky considered all plant remains of the Kuznetsk Basin to belong to Permian alone.

The controversial matter attracted the attention of the writer beginning with his study of the Siberian Paleozoic and Mesozoic floras in 1921-1922 (*3,* pp. 67-68), when he expressed belief that some true Jurassic forms had been mixed with the Paleozoic flora in the collections from the Kuznetsk Basin.[4] This statement, however, remained to be finally verified by a precise and detailed comparison of the Siberian material with Upper Paleozoic and Mesozoic floras elsewhere, to which end the writer has worked subsequently. Thus, while in California (1922-1927) he took advantage of the opportunity to study typical specimens of *Annularia* from the Pennsylvanian of Missouri in a collection of the California Academy of Sciences. This material proved to be of unusual scientific interest and importance, having not only the minute structure beautifully preserved, but besides having a peculiar and new kind of fructification in direct connection with a very typical *Annularia* foliage.

Another angle of interest was added to this research by the observation that the leaves from Missouri, which have been commonly referred to *Annularia stellata* Schlotheim (*31,* p. 159; *32,* p. 25; *22,* p. 425), possess a minute structure undoubtedly not of the type described by Potonie (*16,* pp. 162-169) for *A. stellata* from Europe. The incidentally discovered discrepancy has led to further studies of the question as to which particular type of microstructure must be considered typical for Schlotheim's species. This gradual increase in the scope of the originally limited research, and occupation of the greater part of the writer's time by other activities in geology and paleontology, has greatly delayed publication of this paper.

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The writer takes opportunity to thank Dr. B. W. Evermann and Dr. G. D. Hanna, of the California Academy of Sciences, for the permission to study the museum specimens described in this paper.

4. The same opinion was expressed by Kosmovsky in 1891 (8).

To Dr. David White and to Dr. R. W. Chaney the writer is indebted for reading parts of the manuscript and for helpful suggestions, and for the reading of the whole manuscript he is indebted to Dr. R. C. Moore. Thanks are also due Dr. H. Gothan, of the Preussische Geologische Landesanstalt, who obligingly examined and compared selected sketches and microphotographs of the *Annularia* from Missouri with some European originals.

The photographs of plate XII, and plate XV, figure 2, were made by Mr. A. Christofferson under supervision of Doctor Hanna. The negative of the photograph plate XV, figure 1, belongs to P. E. Afanasieff's studio of San Francisco. All the sketches were prepared by the writer. For the views expressed in this paper, unless otherwise noted, the writer alone is responsible.

DESCRIPTION.

Carpannularia americana Elias new genus and species.

The specimens here described are three slabs of a gray shale with carbonized plant remains along some of the planes of stratification. Part of the shale, especially inside of the slabs, is somewhat hardened and of brownish color, due probably to admixture of carbonates and perhaps of ferric hydroxide. The plant remains in the collection represent the same group of plants as those described by D. White in his well-known monographs *30* and *31,* from the same horizon and possibly the same locality.

Slabs shown on plate XII and plate XIII contain only remains of *Carpannularia americana,* but the specimen, part of which is photographed in plate XV, figure 1, contains many other forms, among which were recognized *Asterophyllites longifolius* (Stb.) Brongn., *Pecopteris clintoni* (?) Lesqx., and *Lepidodendron scutatum* Lesqx.

Cotypes. Nos. 2654-2656, Mus. Calif. Acad. Sci., three slabs from near Clinton, Henry county, Missouri, obtained from Gustav Hambach; age, lower Pennsylvanian.

FOLIAGE. The photograph (Pl. XII) and sketch (Pl. XIII, Fig. 1*a*) show all the peculiarities of the foliage of *Carpannularia.* The general aspects of the whorls, the number of leaves in a whorl, the form of the leaves, their uninervenes, and the mode of attachment—all correspond closely to what is understood under the old term *Annularia.* The leaves of this type from the North American Pennsylvanian were usually described as *Annularia longifolia* Brongn., or as *Annularia stellata* (Schloth.). However, the well-preserved leaves from near Clinton reveal a minute structure which is not the same as

that figured and described by Potonie for the topotypes of *Annularia stellata* (Schloth.) (*16*, Pl. XXIV, Figs. 1-6).

MICROSTRUCTURE OF LEAVES AND COMPARISON WITH *Annularia stellata* AND *A. westphalica* OF EUROPE. The surface of the leaves is completely covered with what appear to be short truncate hairs or bristles or scales which are appressed to the lamina and are arranged in such manner that the whole structure of the leaf may be called featherlike. The "hairs" are more or less parallel to the axis of the leaf along its median part only. On either side they begin gradually to arch and become almost perpendicular to the axis when they reach the margin of the leaf (see Pl. XIV, Fig. 1*a*, 1*b* and Pl. XV, Fig. 2). The angles which these "hairs" form at the margin (which is almost parallel to the axis of the leaf), are 70° to 80° in most cases, but in some they approached 90°. The angle becomes more acute at the base of a leaf (down to 55° and less), and at the very apex of a leaf the "hairs" spread out radially (see sketch, Fig. 1*a*).

The width of the "hairs" is 0.04 mm. (40 μ), their length being about three times as great. The apparently greater length of some "hairs" seems to be due to overlap of neighboring "hairs." There are as many as 20 "hairs" near the margin of the leaf for each 1 mm. along the margin. The size and density of the "hairs" is about the same all over the lamina. In some cases this feature of the microstructure of the leaf is modified in the following manner: The central nerve becomes more prominent, appearing as a roughly striated stripe 0.5 mm. wide. On each side of this there is a transverse striation due to the almost perpendicular, slightly wavy arrangement of the "hairs" (Pl. XIV, Fig. 1*c*). The "hairs" appear here to be slightly narrower than in the case of Pl. XIV, Fig. 1*b*. All in all the leaves forming such a modification of the normal featherlike structure seem to be less well preserved. Probably the transverse arrangement of "hairs" and their less regular form are due to maceration and perhaps to mechanical deformation of the whole structure.

What is most important is that in no single leaf was there noticed a structure similar to that described by Potonie for *Annularia stellata* of Europe; but on all the leaves without exception, whether they were well preserved or not, a featherlike structure or its transverse modification as above described was visible. Furthermore, no lateral grooves, which are so prominent in the Potonie leaves, were ever noticed on the leaves from Missouri and, as far as known

to the writer, they have never been shown or described on any American *Annularia* leaves.

While the visible structure on the leaves from Missouri fits poorly the microstructure of *Annularia stellata* from Thüringen, as described and figured by Potonie, the anatomy of the American leaves does not differ much and possibly is even indistinguishable from some other types of *Annularia* leaves from Europe and elsewhere, as will be shown below. Prior to Potonie's detailed description of *A. stellata* from Thüringen, another able European paleobotanist, D. Stur, published a very clear description of the minute structure of *Annularia* leaves from Schatzlar of Westphalia, which he named *A. westphalica* and *A geinitzi* and which he believed to be different from the leaves of *A. stellata.* The description of what Stur observed on the blades of the Schatzlar leaves fits the visible anatomy of the Missouri leaves as though it were meant for them:

"The upper surface of the lamina of *Annularia westphalica* is specifically distinguished by a very delicate striation which starts from the middle nerve and, through a slight bend with convexity toward the apex, reaches the margins. Striæ are quite thick and short and besides are somewhat wavy, and are so densely crowded that no place without striation can be noticed. Whether this ruggedness indicates short bristles pressed into the lamina, which thus would mean that every striæ corresponds to a hair, I am not able to decide, because I could not notice any decisive cilia."[5]

Unfortunately the natural-size photographs of *A. westphalica* and *A. geinitzi* by Stur did not (and certainly could not) show the described minute structure on the strength of which, chiefly, these leaves have been separated from *A. stellata* Schlotheim. Neither was there a single sketch added to illustrate the peculiar hairiness or ruggedness of the lamina. Furthermore, Stur limited himself to a too brief and incomplete characteristic of *A. stellata* leaves themselves, from which type he claimed his leaves to be different. By failing to present convincing illustrations Stur exposed his views to severe criticism by Potonie, who emphasized some undoubtedly existing points of similarity between the Thüringen and Schatzlar specimens of *Annularia* leaves and concluded that they are specifically identical. The arguments of Potonie, accompanied by elaborate illustrations, convinced the majority of the paleobotanists of the correctness of his views, and since "Die Flora des Rothliegendes von Thüringen" was published, Stur's names *A. westphalica* and *A. geinitzi* were dropped out, being regarded as mere synonyms

5. (30), p. 216, free translation by the writer.

of *A. stellata* Schlotheim. After a detailed comparison of the minute structure of the leaves from Missouri with corresponding features of European *Annularia,* as revealed by Stur and Potonie, the writer concluded that he certainly could not identify his leaves with *A. stellata* from Thüringen, and at the same time he realized that the American leaves were probably similar to Stur's Schatzlar types. The problem of a proper classification of the American leaves with European types was complicated chiefly by the absence of any sketches or detailed quantitative descriptions for the Schatzlar species and, on the other hand, by the possibility, as suggested by D. White,[6] that the sketches by Potonie were not quite accurate.

In order to help this unfortunate situation the writer decided to bring the matter to the attention of W. Gothan, one of the leading German paleobotanists, who very obligingly sent to the writer a topotype of *A. stellata* Schlotheim from Manebach, in Thüringia. Gothan also gave his opinion on the matter as follows:

"What you write and figure of the specimens from Missouri and that of Stur concerns a problem which I already often outlined for myself. This *Annularia westphalica* Stur, etc., shows a much stronger development of hairs, which was known to me long ago on specimens from Saarbrücken and on others; I discussed this often with Dr. Jongmans, but only one decision could be reached. I could not see on these forms from the Upper Westphalian (Westphal C) the lateral grooves of *A. stellata;* the hairiness on the lamina is stronger and often quite rough, as you describe it. I think, therefore, that Stur was right in separation of his species from *A. stellata;* the latter appears to be substantially a Permian-Stephanian form, while the other is early Westphalian. As to the hairs shown on Potonie's sketch, these are generalized, which you can see yourself on the inclosed specimen."[7]

Thanks to the kindness of Gothan the writer is able now to extend his comparative study of *Annularia* to the topotype of *A. stellata* Schlotheim, which is presented here on plate XIV, figures 2*a,* 2*b* and 2*c*. The examination of the topotype makes clear that the minute structure of the leaves of *A. stellata* as sketched by Potonie (*16,* Pl. XXIV, Figs. 1 to 6) was certainly generalized, but not so as to obscure the most important features. The main and perhaps the only discrepancy with the actual structure of the leaves is the erroneous interpretation by Potonie of the striation of the lamina as if it was comparable to hairiness of human or other mammalian skin. Potonie's drawings of the lamina of *A. stellata* leaves show as if very thin hairs are acutely terminated and are not densely spaced. Un-

6. Personal communication to the writer.
7. Translation from letter to the writer, June 1, 1930.

fortunately the shape and arrangement of these hairs were still more generalized on the sketch in the old edition of "Pflanzenpaleontologie" (*17*, text figure 195 on p. 200), which gives an entirely erroneous idea as to the actually observable "hairiness" of the leaves.

According to the microscopic examination of the topotype of *A. stellata*, by the writer, the fine lines which Potonie interpreted as minutely thin hairs are V-shaped depressions which are interconnected to form a netlike structure with meshes elongated along the lamina. The writer was not able to detect any gradual distad thinning or sharpening of the fine depressed lines. Furthermore, these lines are not as disorderly arranged as is shown on the sketches by Potonie, but usually, as can be clearly seen on the better preserved places, they run fairly parallel for a certain distance and then bend strongly to meet the neighboring lines (see Pl. XIV, Fig. 2*c*).

Nevertheless the general idea of more or less longitudinal arrangement of the striæ as expressed by Potonie corresponds satisfactorily to that observed on these leaves. The sketch (Pl. XIV, Fig. 2*b*) shows somewhat schematically the arrangement of striæ on a leaf of the topotype of *A. stellata* Schlotheim from Manebach, which was sent to the writer by W. Gothan. In the leaves of this topotype the striæ are arranged fairly parallel to the axis in the broad middle part of the lamina between the lateral grooves. However, within the grooves the striæ turn slightly but distinctly to the margins and are inclined about 30 degrees to the axis. But again in the lateral rims of the lamina (haütige Blattsaüme of Potonie) the striæ show a very distinct tendency to become parallel to the axis, and they end at the margins with only 5 to 10 degrees or lesser inclination to the latter. The striation in the grooves differs from the striation in the rest of the lamina, also, in being about two times less densely spaced. This was correctly shown by Potonie (*16*, Pl. XXIX, Fig. 5), who believed he had seen stomata in the grooves. Possibly the elongated meshes formed by the broadly spaced striæ of the grooves have been regarded as stomata by Potonie.

The writer was not able to reach any definite conclusion as to the significance of the fine striæ on the *A. stellata* leaves. If the comparatively much wider interspaces between the very fine lines could be interpreted as impressions of bristles or scales comparable to those of *Carpannularia* (see description above), the thin lines will correspond to border lines between crowded and partly superimposed neighboring bristles or scales and thus theoretically will have no

thickness, being merely geometrical lines. But they may also correspond to thin walls between cells of the epidermis, if the broad meshes between fine lines are thus interpreted. Better material than that at the writer's disposal must be examined in order to solve this problem. The topotype examined by the writer represents only impressions of leaves, and the material which left these impressions is practically not preserved at all.

No matter what the true explanation of the striation on the *A. stellata* leaves may be, the striæ on these leaves are spaced regularly enough to be counted when sufficiently well preserved. The writer counted about 35 striæ per 1 millimeter of width in the middle part of the topotype leaves. This is about two times more than the number of bristles or scales per same space on the lamina of leaves of *Carpannularia* from Missouri. Let us come back now to the structure of these American leaves.

The "hairs" or scales, or whatever they were, appear to have been pressed down on the surface of the Missouri leaves, their feather-like arrangement being due, perhaps, to the arrangement of corresponding cells of the epidermis. However, the epidermis itself rarely leaves an impression in the shale, being visible only on a single leaf whose margins are bare of "hairs"; here it is represented by a minutely thin, light-brown colored film with no distinguishable structure. The same light-brown film shows itself here and there at the accidentally bald spots (Pl. XIV, Fig. 1*b*, Pl. XV, Fig. 2), in the middle part of the same leaf, while the other leaves are usually completely covered with the pressed "hairs." They touch and sometimes even overlap others, thus presenting in general a plain or rather slightly "scaly" black imitation of "lamina," the real lamina being hidden beneath.

The sides of the leaves have, as a rule, slightly irregular margins, suggesting a roughly torn tissue. It seems probable that these margins may represent the crushed lateral epidermis of leaves which were originally inflated, the epidermis having been torn as the leaves were flattened in the sediments.

It should be mentioned that Lesquereux described "inflated, semi-cylindrical, club-shaped" leaves which he named *Annularia inflata*.[8] In other respects the latter species is almost indistinguishable from *Annularia longifolia* (*A. stellata* after D. White, *31* and *32*, and other authors) described by Lesquereux from the same locality. Lesquereux states:

8. See (12), p. 47, the form of leaves being shown on Fig. 2*b*, 2*bb*, Pl. II, (10).

"It may be that we have here two parts of the same species, one representing branches growing out of or above water under atmospheric influences, with dry, flat leaflets: *Annularia longifolia;* the other, representing the floating part, sustained in water by bladderly-inflated leaflets, as shown in our species." (*A. inflata* Lesqx.) (*10,* p. 423.)

The flatness of the "flat leaflets" of *A. longifolia* from Mazon creek may be due merely to the circumstances of preservation of these leaves, the survival of the inflated leaves in their original cylindrical form being rather rare, as was realized by Lesquereux himself, who remarked: "It is peculiar that this, so different a form of a common species, has not been found elsewhere and described before" (*10,* p. 423). He himself never found it (*A. inflata*) "distinct or with inflated subcylindrical leaves, except in the concretions of Mazon creek." (*12,* p. 48.)

The writer has seen such inflated leaves in a concretion in the paleontological collections of Stanford University. These seem to be identical with *A. longifolia* Lesqx. and with *Carpannularia americana.* It is probable that the inflated form of leaves of *Carpannularia americana* is their true original form, and if we observe them now as being quite flat this is due only to the alterations which they have suffered after becoming a dead part of the organism to which they belonged. We can easily imagine such inflated leaves to be flattened, when pressed down on the ground or against any hard substance.

The following remark of Lesquereux concerning the inflated leaves is worthy of notice: "This peculiar feature may be the result of habitat under water or in more shaded localities; a casual inflation by superfluence or turgescence of the cellular tissue. The costa, then, is a central vascular bundle, as in leaves of Stigmaria" (*12,* p. 47).

In a few *Carpannularia* segments the faint impression of what we call the central nerve, was observed, located asymmetrically to one side of a leaf. This seems to be an accident of preservation, due to the shifting of the inner vascular bundle to the side, as if there had been nothing inside of an inflated leaf to prevent such a movement.

MEGASTRUCTURE OF LEAVES. The form of the leaf in the specimens is lanceolate or linear-lanceolate. The apex is rounded, but with a spine or mucronate projection at the apex (see Pl. XIV, Fig. 1*a*), suggesting a continuation of the axis of the leaf. The mucronate prolongation "clearly developed at the apices of the shagreened leaves" of *Annularia stellata* from Missouri have been observed by

D. White (*32*, p. 162). The spine is covered by the same kind of "hairs," but here they are still more delicate, crowded and compressed. That this hairy spine was more delicate than the rest of the hairy lamina is indicated by the ease with which it becomes crushed, leaving a very faint impression on the rock. This fact was probably responsible for some descriptions of *Annularia* leaves as being obtuse at the apex.

The above description of the anatomy of the leaves of *Carpannularia* is based on a microscopic study (in reflected light) of a well-preserved whorl (Pl. XII). The sketches (Pl. XIV, Figs. 1*a* and 1*b*) and photograph (Pl. XV, Fig. 2) are from parts of the same specimen. The structure of the leaves of the other specimens from near Clinton and figured here is exactly the same, although it is not so well preserved. There is no doubt that the three represent parts of the same plant.

All of the leaves of mature specimens of *Carpannularia* were spread out from the center in one plane, thus forming a star-shaped whorl. The whorl plane was inclined to the axis of the branch and in all specimens observed the proximal end of the whorl lies above the axis. As seen on an excellently preserved branch (Pl. XII), the whorls are ovoid or egg-shaped in outline, the distal part almost (but not exactly) circular and the longitudinal axis only slightly longer than the transverse axis of a whorl. As a rule the leaves in a whorl vary in length, gradually filling the egg-shaped outline; the occurrence of some slightly smaller leaves among the larger ones does not detract much from the egg-shaped form of the whole.

The center of the egg-shaped whorls, or the place of their attachment to the nodes of a branch, is located slightly eccentrically and nearer to their proximal part. Thus the leaves of the proximal part are slightly shorter than those of the distal part. But the lateral leaves are the shortest of all in a whorl. It is pointed out that the shape of the whorls is somewhat different from that which is commonly given for *Annularia*. Seward in his textbook, "Fossil Plants," says that in the genus *Annularia* "the lateral segments are usually longer than the upper and lower members of a whorl" (*24*, p. 337). In our egg-shaped whorls, as stated above, the distal and the proximal leaves of a whorl are slightly longer that the lateral ones.

A distinct ovoid or egg-shaped form of the whorls was shown on Lesquereux's figure 1, plate XX of his *Annularia inflata* (*10*). The

whorls along a branch overlap each other, the overlap usually extending from ¼ to ½ (and even more) of the diameter of a whorl.

Figure 2 of plate XIII shows a partly opened whorl. This probably represents a younger stage, which every whorl in its development passed through. Such an unopened whorl is represented also by the specimen of inflated leaves in the Stanford University collection, already mentioned.

A still earlier stage of development of *Annularia* whorls may be represented on Lesquereux's plate XXI, Figure 1 (*10*).

The number of leaves in a whorl varies ordinarily from 17 to 29, the number 24 being the most common.[9] The number of leaves in lateral branches of a compound branch decreases gradually toward the end of a branch (see Pl. XIII, Fig. 1*a*; see, also Lesquereux *11*, Fig. 1, Pl. II), with decrease in the size of the leaves.

The length of leaves in normal whorls (Pl. XII) varies ordinarily from 17 to 24 mm., not including the mucro, the length of which is usually 1 mm., while the width of leaves varies from 1½ to 3½ mm.

The ratio of a shortest to a longest leaf within a whorl was found to be 1 : 1.2 (measured without mucro and not counting abnormally short leaves).

The ratio of width to length (without mucro) of a leaf was found to be 1 : 7 to 8.

SHEATHS. The leaves are united basally into a collar, or sheath, the latter being very short and conical as is characteristic of *Annularia*, contrasting with the longer, cylindrical sheaths of *Phyllotheca* and *Equisetites*. The sheath of our plant is of a very delicate nature and is not covered with the "hairs," which are so densely developed on the distal free portion of leaves.

DIAPHRAGMS. A distinct circular or oval diaphragm is often seen at the node of a stem, in the center of each whorl. These diaphragms consist of a circle of small dotlike or slightly elongated depressions, which are sometimes not very distinctly separated from each other. They seem to correspond in number to the leaves of the whorls.

INTERNODES. Internodes are very slender, with a rather faint parallel striation along them. The carbonaceous film of the internode is very thin (thinner than that of the leaves) and is easily crushed so that the corresponding impression on the shale is very weak. The internodes are often slightly curved. The width of the internode in

9. D. White counted 27 leaves in a verticil of *Annularia stellata* (= *C. americana*) from the vicinity of Clinton, Mo. Some leaves of the same plant from Hobbs' bank have been found by the same author to be "nearly 5 cm. in length." See (32), p. 162.

the flattened state usually varies from 1½ to 2½ mm., but in the specimen (Pl. XIII, Fig. 2), which obviously came from the lower part of the plant, the axis reaches 8 mm. in width. In spite of this much greater width the carbonaceous film, which represents the fossilized remnant of the axis, is still very thin. This and obvious twisting of one internode about 180° around the axis suggest a very slender axis, probably a hollow cylinder with a thin outer wall.

All in all the axis appears to have been almost too slender to support in the air the numerous and heavy leaves of the whorls.

It is not improbable that *Carpannularia* was a hydrophyte or water plant, as was suggested by Lesquereux for his *Annularia inflata,* which is probably identical with *Carpannularia americana.*[10]

Fructification. On the sketch (Pl. XIV, Fig. 3*a*) three seedlike bodies together with the leaves at the nodes of a branch are shown. The photograph, plate XV, figure 1, shows the same specimen. In this paper these bodies will be called *seeds* in the same sense as this term is applied to the seedlike fruits of pteridosperms. Their nature is discussed below.

The seeds are 7 to 7.5 mm. long and 5 to 6 mm. broad, in this flattened state of preservation. The thickness of these flattened seeds is several times that of the thin black films representing the carbonized matter of the rachis and of the leaves of the same branch. The interior of the seeds seems to consist now of clay, but at their bases they are impregnated by yellowish-brown ochre, probably ferric hydroxide (shown by cross-hatching in the sketch Pl. XIV, Fig. 3*c*) which continues into the sheath at the base of each seed. The exterior of the seeds is covered with a delicate carbonaceous film on which numerous short and wavy longitudinal striæ are seen under the microscope (see Pl. XIV, Fig. 3*c*). The average thickness of the flattened seeds is about 0.5 mm.

The seeds are rounded at the base and provided with a broad but very short basal extension by which they were connected with the node. The apex is somewhat narrowed like a bottleneck. The corroded surface of the seeds shows the coriaceous nature of the envelope and suggests a shrunken or passed-out interior.

In their appearance these seeds resemble very much the branch tubers of *Equisetites burchardti* Dunker from the Wealden of England, which were so perfectly shown and described by A. C. Seward.[11]

10. For explanation why these remains must retain separate generic and specific names, see p. 137 of this paper.

11. See (23), Pl. I. Fig. 5, or (24), Fig. 65 on p. 279.

In the description of this Wealden tuber it is stated that "its surface is somewhat sunk and shriveled and the apex is surrounded by a nodal leaf-sheath," which seems to describe the appearance of the Missouri fructification fairly well except that there are no nodal leaf sheaths on the seeds. The seeds are located among the leaves occurring in regularly developed star-shaped whorls, and these latter could hardly develop so freely under the ground. In fact, *Annularia* and similar whorls were never considered by any paleobotanist as the underground organs of a plant. Thus our seeds, attached at the similar whorls, cannot be considered as underground tubers, but represent a superficial fructification of a plant, with their shape and outer structure comparable to the seeds of pteridosperms and also to some cordaitean seeds.

Close to the uppermost seed of the branch shown in plate XIV, fig. 3*a*, an irregularly rounded, brownish body (A) may be seen. It seems to me that this may be the remains of the interior of the seed, pressed out of the envelope or seed coat.

Numerous other bodies of the same color, composition, and of about the same size, but not split, and having a regular, slightly elongated discoidal form are seen here and there scattered on the same surface of the slab. Thirteen bodies of this kind have been found, for the most part crowded around the seed-bearing branch and rare or absent in the distant parts of the slab. All these bodies are alike in size (see Pl. XIV, Fig. 3*b*). There is no carbonaceous matter in these, and they seem to be without structure. They are composed of brown compact matter.[12]

The leaves on both sides of each of our seeds are distinctly curved, the concave sides facing a seed (Pl. XIV, Fig. 3*a*, Pl. XV, Fig. 1), as if these leaves were forced outwards by the intensive development of the seed.

Besides this curvature there is another peculiar feature in some of the leaves which overarch a seed. One of each two surrounding leaves (B) shows usually an abnormal structure and is somewhat narrower than the rest of the leaves of the fertile whorls. The abnormality of such a leaf is shown in the easier crushing out from the rock of the middle part of the carbonized film of the leaf, while in the other leaves of these whorls the lateral parts of carbonized film are crushed out of the rock first and the middle part (the central

12. It seems improbable that they represent merely small mineral concretions, because they have a too uniform size and form, but their relation to the "seeds" of *Carpannularia* cannot be certainly determined at present.

nerve) is almost always present. Furthermore, the carbonized film of the abnormal leaf is somewhat thicker and more scaly in comparison with that of the normal leaf.

Three seeds in all are seen on the specimen. They are all preserved at the place of their normal attachment among the leaves of the whorls. The seed in the lowest whorl is well preserved and is surrounded by curved leaves at the sides. One of these leaves has the abnormal structure described above. Unfortunately almost the entire lower half of this whorl was broken away from the specimen, and it is a question if any more seeds were attached to the same whorl. The space remaining seems sufficient for but one seed.

There are two seeds attached to the next whorl above. One of these is well preserved. Close to this the irregular brownish body already described is seen. One curved, abnormal leaf is preserved on the lower side of this seed. On the other side of it is a set of distinctly curved leaves, which straighten out gradually from the seed (one of these leaves which is the nearest to the seed is unfortunately almost completely broken away).

The other seed in the same whorl has an irregularly shaped apex and the leaves around it are broken away. However, its regular position relative to the node of the whorl leaves no doubt as to its belonging to the same whorl. The terminal of this seed is abrupt and there may be seen yellow ochre of the same kind as at the bases of this and other seeds.

There seems to be no room on the whorl for any more seeds; thus it appears that the two-seeded whorl was probably characteristic of *Carpannularia americana.*

The two-seeded whorl of the specimen has the seeds separated by 5 leaves on one side and by 13 leaves on the other; some leaves are obviously missing from this whorl and it seems probable that the original number of leaves and seeds in this whorl was close to 24, with about 6 and 16 leaves between the seeds.

The next whorl (along the branch, see Pl. XIV, Fig. 3*a*) does not bear any seeds. This fact indicates that the fructification, at least in part, was located below the terminus of the branches.

The distance between the two seed-bearing whorls is 19 mm. and the distance between the upper two whorls is 30 mm.; thus the distance between the seed-bearing and the sterile whorl is 1½ times greater than that between the two fertile whorls. On the ordinary sterile branches, as well as on the compound branch with brushlike

appendages (see Pl. XIII, Fig. 1*a*, described below), the distances between the whorls of the same branch are more or less regular, as a rule. Occasionally, however, some internodes are much shorter than the rest, as is seen in the third right branch, shown in plate XIII, figure 1*a*.

As already stated, there are no stalklike supports for the seeds of *Carpannularia*. The location of seeds in one plane with the leaves of a whorl, as well as the arching of the neighboring leaves around the seeds, suggest their simultaneous development with the leaves of the whorls. The seeds seem to be quite homologous to the sterile members of the whorls, differing only in being adapted to function in reproduction. It appears to be clear that their development as reproductive organs has caused the above-described abnormalities in the neighboring leaves.

Though the internal structure of *Carpannularia* fruits remains unknown to us, the observed external features permit conclusion that the fruits could be hardly interpreted as sporangia. Both the living horsetails and all the numerous extinct Equisetales known to us have their sporangia aggregated to form a definite strobilus or spore-bearing cone, which is a most essential characteristic of the whole class. The above-described fructification of *Carpannularia* is therefore so much different from the typical strobily of Equisetales that one cannot help but conclude the *Carpannularia* must not be classified with Equisetales, no matter how much the stem and leaves of the plant may resemble the extinct and modern horsetails. The appearance of the seed-like fruits of *Carpannularia* on the shoots with foliage closely resembling leaves of the extinct Equisetales is indeed very surprising, but is it any more surprising than the well-known association of horsetaillike foliage with flowers and seed-bearing cones in the "living fossil" *Casuarina* of Australia?

It seems to the writer that the development of the seedlike bodies among the leaves of typical vegetative whorls of *Annularia* type has all the appearance of an innovation in the way of reproduction, and it seems to him quite possible that at about this time the *Equisetum*-like phanerogamic plants made their first appearance. It is well to recall that the father of modern paleobotany, Brongniart, and his ablest pupil, Renault, always believed in the existence of phanerogamic Calamariaceæ in the Paleozoic, though, as was pointed out by their English contemporaries, they did not have decisive evidence in support of this view at hand. The controversial subject was well summarized by Scott in the following way (*21*, p. 81):

"If M. Renault's view that a certain part of the Calamarieæ bore seeds were tenable, we should have the remarkable case of a transition from cryptogamic to phanerogamic plants within the limits of a single family. For this conclusion, though not without analogy,[13] there is, as yet, no satisfactory evidence in this case."

The presently described *Carpannularia* fruits appear to supply this long-delayed evidence favoring the view of Brongniart modified by Renault, because these seed-like bodies in question apparently show development of an unusual and new kind of fructification on a plant otherwise indistinguishable from the typical Upper Paleozoic Equisetales. Whatever the relation of *Carpannularia* to the living *Equisetum*-like phanerogams might be, it is clear enough that the former is a much more primitive type. *Carpannularia* does not bear its fruits on a stalklike support or branches, and its fruits originate more or less simultaneously with the rest of the foliage of the whorl to which they belong. This is proved by the direct influence which the seedlike bodies have on the leaves which immediately surround them. Compare with this the development of both male and female flowers of *Ephedra,* another living phanerogam with *Equisetum*-like foliage, or the appearance of cones in arboreous *Casuarina.* The fruits of these living plants develop on separate stalks which break through the leaves reduced to sheets at the nodes. The reduced foliage of these plants develops earlier and together with the appearance of new shoots to which they belong. The above-mentioned living fruits, on the other hand, appear much later than the sheets through which they break, and their only relation to this reduced foliage is that they incidentally are borne on the same nodes, around which the sheet of leaves have earlier originated.

It may be pointed out, furthermore, that the flowers of the living *Equisetum*-like phanerogams are certainly of a much more advanced type than the fertile organs of *Carpannularia.* The latter with their peculiarly modified surrounding leaves form a very primitive flower, indeed, or as we are perhaps justified to say, they represent a highly interesting *flower in the making.*

Brushlike Appendages. There is one compound branch in the material from Clinton which bears whorls of somewhat smaller size than those of the other specimens. This seems to indicate a more or less terminal position of such branches. As a matter of fact, when regarding an *Annularia* branch one can almost always recognize its distal end by the decrease in size of the whorls, with a corresponding

13. Scott refers to the case of some of the Paleozoic Lycopods, on which there was discovered "a kind of ovule or seed which may probably have been fertilized, or at least pollinated, while still on the plant," see (21), p. 194.

decrease in the number of leaves in a whorl.[14] The smaller size and smaller number of segments in a whorl toward the end of a branch is not so much due to younger age of the more terminal whorls (the apical growth was in all probability the mode of growth of the plant), but to their position on the axis, for the number of leaves obviously did not change with the growth of whorls, all the leaves in a whorl developing simultaneously.

The ordinary leaves constituting the whorls of the branch shown on plate XIII, figure 1*a* do not differ from the leaves of the other specimens of *Carpannularia americana* by any character except that they are slightly smaller.

There is, however, a peculiar modification of some of the leaves in the whorls of the main (central) axis of our compound branch. The proximal halves of these whorls consist of peculiar brushlike appendages which take the place of the normal leaves of these whorls, being their modified equivalents. Some of these appendages are obviously broken away or simply hidden underneath the axis and the overlapping leaves of the proximal half of the next whorl. It was not attempted to uncover all these appendages, because it would have resulted in the destruction of the overlapping stems and leaves. The distal halves of the uppermost central whorls of this specimen are not visible, and we therefore cannot say at present how close to the apex of a branch these appendages have been situated.

The number of visible appendages in the specimen varies from 3 to 10 in the whorl. The number of the preserved proximal normal leaves in the same whorls is 8 or 9. We may surmise regarding the obvious accidental lack of some of the appendages and leaves in these whorls that the total number of all these members in a whorl was near 24, and that while the proximal half of each of these whorls was made up of the normal leaves, the distal half was composed of the hairy appendages only. The number of dotlike depressions constituting the diaphragms of the nodes to which these whorls were attached is also about 24. From each of the nodes with these whorls two symmetrical lateral branches are given off immediately above the whorls and in one plane with the central axis.[15]

14. See, for instance, Fig. 1, Pl. 2, (11) or Pl. XII and Pl. XIII, Fig. 1*a* of this paper.

15. There is another branch with hairy appendages which was uncovered later on the same slab on which the seed-bearing branch of *Carpannularia* was discovered. This branch has a comparatively thick central axis (see sketch Pl. XIV, Fig. 4). At each node of the axis a few hairy appendages are seen surrounding the bases of lateral branches, which are given off almost perpendicularly. The appendages are curved considerably. The central axis is richly impregnated with brown ochre at the bases of lateral branches. The latter are provided with regular, large-size whorls of normal leaves with the common featherlike structure.

The brushlike appendages (see Pl. XIII, Figs. 1*a* and 1*b*) consist of very delicate and crowded hairs, which are given off at a very acute angle from the axis of the appendage; this axis, however, is not visible and leaves no impression on the shale. It is marked merely by a bundle of parallel hairs in the middle of the appendage, the widest part of which is always at the very base. The appendage narrows gradually toward the apex, which closely resembles the hairy, slender mucro of the normal leaf, but is somewhat longer and grades with but a gentle change of width down to the hairy appendage (see Pl. XIII, Fig. 1*b*). It should be pointed out that in normal leaves the mucro is situated on an obtuse apex, and that the widest part of a normal leaf is nearer to its apex than to its base (see Pl. XIV, Fig. 1*a*).

The hairy appendages of *Carpannularia* resemble somewhat the leaves of *Pseudobornia ursina* Nathorst from the Upper Devonian of Bear Island (*26,* Fig. 117-c on p. 8), but are simpler and more regular in structure and have wider bases. They resemble, also, the linear hairy bracts of some Cycadoidea flowers (see *33,* Fig. 69 on p. 136 and others, or *27,* Figs. 513, 514 on pp. 380, 381 and Fig. 533, p. 410).

The position of these appendages at the base of lateral, sterile branches suggests that these peculiar organs have something in common with the so-called Aphlebiæ of some pteridosperms and ferns. But in their structure they do not resemble either Aphlebiæ or any other kind of protective leaflets or scale leaves of the plant kingdom known to the writer.

A question may arise, also, whether they can be regarded as male flowers of the plant, but since no stamens have been observed on the appendages of both branches examined, the interpretation of these structures as male flowers must remain open to question.

Characteristics of *Carpannularia americana. Stem slender, articulate, simple or with symmetrical lateral branches; ovoid whorls of the Annularia type with 19 to 28 leaves spreading in one plane (in maturity) filling an ovoid contour and united basally into a short and conelike sheath. Leaves linear-lanceolate with a broad but not prominent nerve and with mucros at the obtuse apices. Upper surface of leaves covered completely by very small and short "hairs" arranged in a featherlike structure.*

Reproduction by seeds, developed in the place of one or two ordinary leaves of a whorl. Envelope of seeds coriaceous, rounded at the base and with a very short bottle-neck shaped apex. Surrounding

leaves overarch the seeds being in the same plane with them. No fertile whorls have been found on the terminals of the branches.

The brushlike appendages taking the place of ordinary leaves at the bases of the lateral branches may represent male flowers of the plant, or simply represent a heteromorphous modification of normal leaves.

CHARACTERISTICS OF GENUS CARPANNULARIA AND ITS POSITION IN PLANT KINGDOM. The characterization of a genus is as a rule based on a study of more than one species included in the genus in question. In our case we have but one species for the newly established genus *Carpannularia,* and any generic characterization cannot be, naturally, a very satisfactory one.

However, the following features may be chosen as a diagnosis of *Carpannularia* for present:

Stem slender, articulate, with whorled leaves united basally into a sheath. The anatomy of leaves reveals a featherlike arrangement of constituent elements. A single central vein traverses a leaf.

Reproduction by seeds, arranged not in cones, but developing among the leaves of a whorl.

The articulate *Equisetum*-like structure of the vegetative organs is certainly a very essential feature of the genus. This feature, together with the mode of reproduction and of development of the seeds among the leaves of ordinary whorls, may be regarded, perhaps, as diagnostic for a new family related to Arthrophyta, in essentially the same way as the extinct Pteriodspermeæ are related to Pteridophyta. The family might correspondingly be named Arthrospermeæ.

In view of the above-described new kind of fructification in direct connection with *Annularia* type of foliage a brief review of the previously known fertile organs pertaining to Annularias and other Equisetales of Paleozoic appears to be desirable.

FRUITS AND LEAVES OF THE UPPER PALEOZOIC EQUISETALES.

The cones of the Upper Paleozoic Equisetales are classified chiefly according to the mode of attachment of the sporangia which are regularly spaced along the axes of the strobili and are provided with sterile bracts. The best-known types of the strobili are as follows:

1—*Calamostachys,* with the fertile whorls separated by the intermediate bracts.

2—*Paleostachya,* with the sporangiophores attached immediately above the bracts.

3—*Cingularia,* with the sporangiophores attached immediately below the bracts.

4—*Archeocalamites,* without any bracts at all, like in living *Equisetum.*
5—*Macrostachya,* exceptionally large and heterosporous cones.[16]

To the ancient *Archeocalamites* cones belong the peculiar forked foliage, resembling very much the leaves of the extinct *Dicranophyllum.* The foliage of the rare *Cingularia* is unknown. The remaining three types of the strobili are referred to the various types of simple and not forked *Equisetum*-like leaves of Upper Carboniferous and Permian. These leaves are known under the names *Annularia, Asterophyllites, Calamocladus* and others, but their generic classification is far from perfect and certainly has no botanical value, the leaves of the same genus being found associated with more than one generic type of cones, and *vice versa,* the generically different leaves being proved to bear the strobili of the same generic type. For instance, both *Calamostachys* and *Paleostachya* cones were found in direct connection with *Annularia* type of foliage,[17] while the *Asterophyllites* vegetation was found with all three generic types of cones: *Calamostachys, Paleostachya* and *Macrostachya.* The material from Missouri described in this paper demonstrates that the leaves commonly referred to *Annularia stellata* or to *A. longifolia* belong in part to a seed-bearing plant, *Carpannularia americana,* which proves that the foliage of *Annularia* type is even not restricted to the class of Equisetales.

The unsatisfactory situation with the present classification of the Upper Paleozoic foliage in question is largely due to lack of knowledge of the anatomy of the greater majority of these leaves, which are at present united in generic groups on such unsatisfactory grounds as the arrangement of whorled leaves in one plane (*Annularia*) or radiating in all directions of the space (*Asterophyllites*). In connection with the above-made description of the anatomy of some important types of *Annularia* foliage a general review of some of the better-known types of leaves commonly referred to *Annularia* and related genera is quite appropriate. Unfortunately, the scant material at hand does not permit the writer to undertake a thorough revision of all these leaves which they most certainly deserve. Therefore, no new generic arrangements or names are proposed, though the groups of leaves as outlined below are possibly of generic distinction.

16. The microsporangia and megasporangia have been discovered also on *Calamostachys casheana* Williamson.

17. Strobili of *Paleostachya* type, which was supposed to be exclusively *Asterophyllites* fructification, were discovered recently in direct connection with *Annularia* leaves (18).

UPPER PALEOZOIC LEAVES OF ANNULARIA TYPE.

Group of *Annularia stellata* (Schlotheim) s. s.

Holotype: 1820—*Casuarinites stellatus* Schlotheim. Beschreibung. . . . und Pflanzen-Versteinerung, Gotha. 1804, Taf. I, Fig. 1, Taf. II, Fig. 3; and Petrefactenkunde, Gotha, 1820, s. 397.

Topotype: 1893—*Annularia stellata* Potonie. Abhandlungen K. Preussischen Geologischen Landesanstalt. (N. F.) Heft 9, s. 162, Taf. XXIV, Figs. 1, 3, 4, 5 and 6. Probably not Fig. 2.

Not 1887—*Annularia westphalica* Stur. Abhandlungen K. K. Geologischen Reichsanstalt, Wien, XI Bd., 2 Abth., s. 213, Taf. XIII b, Fig. 2, bei a, Taf. IV b, Fig. 4.

Not 1887—*Annularia geinitzi* Stur, ibid., s. 51 and 215, Taf. XVIb.

The anatomical features of *A. stellata* s. s. leaves were discussed to some length on the preceding pages of this paper. The leaves can be recognized chiefly by the general longitudinal arrangement of relatively faint striation, which may be, but probably is not, due to the "hairiness" of the lamina. The leaves are supposed to be uninerved, but one does not see anything like median nerve on the lamina, unless the whole wide space between the lateral grooves is considered a "nerve." The presence of the two lateral grooves with somewhat inclined striation within them, is very characteristic for these leaves. The leaves appear to be more nearly linear in outline than the leaves of the next group (group of *A. westphalica*). The whorls of figure 2 on plate XXIV, by Potonie, probably do not belong to *A. stellata,* having a much different shape of leaves. They may belong to *A. westphalica* group or they may represent an intermediate type between the two groups.

It is very difficult to decide at present which of the very numerous leaves referred by various authors to *Annularia stellata* Schlotheim actually belong to this group. According to a special investigation by D. White (see the quotation of the personal communication on p. 138) a great many of both European and American specimens labeled in the collections as *A. stellata* possess the typical anatomy of *Carpannularia americana* type described in this paper, and not the minute structure as described for *A. stellata* by Potonie.

It is possible that the leaves with typical *A. stellata* anatomy are restricted to Upper Stephanian and Permian, as is suggested by Gothan (see the personal communication to the writer, p. 121 of this paper).

Group of *Annularia westphalica* and *Carpannularia americana.*

Cotypes: 1887—*Annularia westphalica* and *Asterophyllites westphalicus* Stur. Abhandlungen, K. K. geologischen Reichsantalt, Wien, XI Bd., 2 Abth., s. 213, Taf. XIII b, Fig. 2, bei a, Taf. IV b, Fig. 4.

The anatomical character of the leaves was discussed in full in the preceding paragraphs. The leaves of this group are characterized by the featherlike arrangement of dense, short and comparatively rough "hairs" or scales which are appressed to the lamina. No sharply defined median vein is usually observed, but the hairs longitudinally arranged along the middle portion of the leaves and a corresponding slight median elevation create an appearance of an obscure nerve, the actual nerve being possibly hidden inside of a thick lamina. To this group of leaves most probably belong *Annularia geinitzi* Stur, the leaves of *Carpannularia americana* and many other Pennsylvanian leaves described under the names *A. stellata, A. longifolia,* and others.

It is impossible at present to compare specifically the *Carpannularia* leaves from Missouri with either of the two Stur types. Generally speaking, no claim can be made at present that all the leaves which have the anatomical features of *Carpannularia* foliage actually belong to this seed-bearing plant. Therefore, in accordance with the modern paleobotanical practice, the sterile organs with the anatomical features of *Carpannularia* leaves but with no fructification attached must be designated by some other generic and specific name. Temporarily such leaves can still be called *Annularia,* with an understanding, however, that they do not necessarily represent a spore-bearing plant. That not all of the *Annularia* leaves belong to Calamitean shoots was known long ago.

Those North American Pennsylvanian leaves which possess the structure of *Carpannularia* foliage, but which cannot be definitely referred to this genus, may be classified at present with *Annularia inflata* Lesquereux emended so as to include not only actually inflated leaves for which this term was originally introduced, but also flattened leaves which in other respects do not differ from var. *inflata* and were believed by Lesquereux to belong probably to the same plant. It was suggested above that the flattened leaves were originally inflated and became crushed after being buried in the sediments.

Part of the European carboniferous leaves formerly classified with *Annularia stellata* Schlotheim must be referred to *A. westphalica, A. geinitzi* or to other species, according to their anatomy, which must

be closely studied in every particular case before a reclassification is attempted.

There are good reasons to believe that a great deal of North American, European and North Asiatic leaves of *Annularia* types have their anatomy sufficiently preserved for recognition of at least a general trend of the striation on their laminas, and in many cases the striæ are as much preserved as to allow measure of their width or their count per given space, or both. It is enough to say that in many modern papers on the Upper Paleozoic floras the striation of *Annularia* foliage is clearly demonstrated on the fine enlarged photographs, though for some reason remained undescribed in the accompanying explanations or in the text.[18]

In connection with the writer's research in the *Annularia* foliage D. White made a very interesting investigation of the apparent microstructure of the *Annularia* leaves in the National Museum. The following is the result of his research:[19]

"The inspection of the museum material shows that most of the specimens exhibit in some portion or other of the leaves 'striation,' consisting of the impressions or molds of short, spinelike, sometimes slightly curved epidermal hairs, generally appressed, more or less parallel, and lying in trends that are oblique near the midrib and curve gradually outward to the margin, as you show in your figure from Missouri. These features are purely epidermal, and though related to hairs, they suggest minute spines in their thornlike aspect, tapering upward, and their rigidity. They are not always parallel and the perfection of the depression depends upon the state of preservation of the leaf. I find these minute thornlike appressed hairs in both the young and the old leaves though they are generally stronger in the older leaves. They are nearly always to be seen in the specimens from Mazon creek, Illinois, where they are apt to be longer and longitudinal in direction along the midrib. Good illustrations are Nos. 17900 and 17875 in the Lacoe collection.

"The same phase, though less coarse and distinct, is seen in a specimen from the lower Permian of Correze in France and at St. Etienne in France (17921). The hairs are particularly well seen also in specimens from Cape Breton (17881), Cannelton, Pa., Yell county, Arkansas, Rhode Island, and the anthracite field of Pennsylvania. The feature is less distinct in the lower Permian at Wiseville, W. Va., and at Lansing, Kan.

"In a few of the American specimens, in which the leaves evidently were somewhat macerated, one discerns a faint transverse ridging between the midrib and the border of the leaf. This feature is particularly clear in a somewhat macerated but well-carbonized specimen from the Forest of Dean, Gloucestershire, England (17920), where carbonaceous lines tapering peripherad and suggesting nerves appear to pass from the midrib to the margin. Though

18. Compare Fig. 2, Pl. 6 in (7), which is referred to *Annularia radiata* Brongn. Also Fig. 9, Pl. 1 in (6), which is classified with *Annularia maxima* Schenk.

19. From personal letter of David White to the writer of May 2, 1928.

these resemble nerves it is more likely that they represent a subepidermal structure, possibly trabeculæ. Though they are very distinct in the Forest of Dean specimen, they are more or less dimly seen in several of the American specimens, all of which are evidently somewhat macerated.

"Further, a portion of one of the leaves from the Forest of Dean shows the impression of the outer surface of the cuticle, which is faintly feathered, as in some of the American specimens. On the whole the feather structure seems to be characteristic of *Annularia* and is, as I suspected would be found to be the case, present in all specimens that are well preserved."

The last remark by White proved to be, however, not quite justified because, as was discussed above, the topotypes of *Annularia stellata* of Europe actually have not the featherlike arrangement of striæ and therefore this latter type of microstructure cannot be considered a universal type for all the leaves which have been commonly referred to *Annularia,* though the majority of *Annularia* type of leaves have probably featherlike to transverse arrangement of minute striæ.

A very interesting observation was related by D. White concerning the striæ on the leaves from the Lower Permian of France; the striæ in these leaves, as he writes, being "less coarse and distinct." Comparing this comment by White with the observation by Gothan that the hairiness of the Westphalian leaves is "stronger and often quite rough," [20] one may question if the coarser structure of *Annularia* foliage of *stellata* types of Pennsylvanian is not a general feature of their distinction from somewhat similar foliage of the Permian of the Northern Hemisphere.

Another still more interesting feature which may possibly characterize another distinct subgenus of the *Annularia* group is mentioned by D. White for the "somewhat macerated but well-carbonized specimen from the Forest of Dean, Gloucestershire, England (17920), where carbonaceous lines tapering peripherad and suggesting nerves appear to pass from the midrib to the margin."[21]

The writer must emphasize that the bristles or scales of *Carpannularia* leaves show no tendency to taper at all, and being short and often slightly overlapping each other, they certainly do not resemble veins (see Pl. XIV, Fig. 1*b* and Pl. XV, Fig. 2). It seems quite possible that the Forest of Dean leaves may be compared with the Siberian *Annularia* leaves which are discussed below.

20. Personal communication quoted on page 121.
21. White—Personal communication quoted on page 138.

Group of *Annularia zalesskii* Elias n. sp.

(Pl. XVI, Fig. 1.)

The following specimens from Siberia belong to this group:

1879—pars *Cyclopitys nordenskioldi* Schmalhausen non Heer, Mém. Acad. Sciences St. Pétersbourg, VII série, Tome XXVII, No. 4. Pl. VI, Figs. 4, 5; Pl. XIV, Figs. 6-8. Not Pl. II, Fig. 1; Pl. V, Figs. 2, 3, 6 and 10.

1918—pars *Phyllotheca stschurowskii* Zalessky non Schmalhausen, Mem. Comitè Géologique Nouv. Serie, Livr. 174. Pl. XV, Fig. 6; Pl. XXIV, Figs. 1, 3-6; Pl. XXV, Figs. 5-7a; Pl. XXVI, Figs. 4, 4a; Pl. LIII, Figs. 1, 1a, 7, 7a. Not Pl. XXV, Figs. 1-3; Pl. XXVI, Fig. 2; Pl. XXX, Figs. 1, 1a; Pl. XXXI, Fig. 1; Pl. XXXVIII, Fig. 2; Pl. XL, Figs. 3, 4; Pl. XLVIII, Fig. 5; Pl. XLIX, Fig. 2.[22]

The leaves are very much like those of the preceding group and have generally a similar featherlike to transverse striation of the lamina. They differ, however, in having a prominent and sharply defined midrib from which the lateral slightly oblique but never quite perpendicular minute striæ come out much like thin veins of some *Tæniopteris* foliage. Nevertheless these striæ are not equivalents of the veins or nerves, because they are so densely spaced that there is no room for soft tissue or parenchyma between the would-be veins.

The absence of the Siberian originals at hand does not permit the writer to judge whether the striæ in these leaves are entire or are made of subsequently connected or overlapping rugæ comparable to what is observed on the above-described leaves from Missouri. The enlarged photographs prepared by A. S. Shestakow for Zalessky (*35*, Pl. LIII, Figs. 1*a* and 7*a*) show quite clearly, however, that the lateral striation of Siberian leaves is quite regular and that it is possible to count the number of striæ per given distance. If the judgment of the writer based on the enlarged photograph is correct there are about 14 striæ per 1 mm. in *Annularia zalesskii*. The middle nerve in these leaves is prominent and sharply defined, and it is often clearly subdivided into three equally prominent ribs by two sharp longitudinal grooves (observation by the writer).

It is possible that *Annularia* leaves from Kuznetsk basin belong to more than one species. The leaves illustrated on figures 1 and 1*a*, plate LIII (*35*) are chosen by the writer as holotype for *Annularia zalesskii*.

The key-table I on page 141 presents in summarized form the essential features of distinction between the leaves of the three groups of *Annularia* leaves which are discussed in this paper.

22. The specimens photographed by Zalessky include almost all specimens sketched by Schmalhausen.

I. Key-table of principal anatomical features of some Annularia leaves.

SPECIES.	Median nerve.	Lateral grooves.	Minute striation.
Annularia stellata (Schlotheim)	None.	Prominent.	Generally longitudinal. Inclined about 30 degrees to the axis within the grooves. About 35 striæ per 1 mm.
Annularia inflata Lesquereux and *Carpannularia americana* Elias	In form of prominent but not sharply defined rib.	None.	Arranged in featherlike fashion. Striation is parallel to the axis along median part only. On both sides striæ bend with convexity toward the apex and become perpendicular to the axis at the margins. About 20 striæ per 1 mm. Striæ short, about three times longer than wide.
Annularia zalesskii Elias	In form of prominent, sharply defined rib.	None.	Arranged like nerves of Tæniopteris foliage. Almost, but not quite, perpendicular to the sharp edges of mid-rib, being slightly turned toward the apex. About 14 striæ per 1 mm.*

* Counted on enlarged photograph; thus to be verified on the original.

II. Key table for identification of some linear leaves.

SPECIES.	Appearance in state of fossilization.	Median vein.	Striation.		Margins.
			Longitudinal.	Transverse.	
Annularia zalesskii	Leaves united in star-shaped whorls.	In form of prominent ridge.	None.	Featherlike, very dense, about 14 striæ per 1 mm.	Wavy.
Phyllotheca stschurowskii	Leaves united in star-shaped whorls.	In form of a dark line.	Straight, not dense, about 5 striæ per 1 mm.	None.	Gently and regularly curved.
Pityophyllum nordenskioldi	Always detached and mostly fragmentary leaves.	In form of a prominent ridge.	Very fine, straight, very dense, about 15 or more striæ per 1 mm.	Coarse, irregular wrinkling.	Straight.

ANNULARIA, PHYLLOTHECA AND PITYOPHYLLUM OF THE CONTROVERSIAL FLORAS OF KUZNETSK BASIN, SIBERIA, AND THEIR DISTINCTION.

Annularia zalesskii leaves are fairly common in Kuznetsk basin and some other areas of Siberia and have been a subject of a long controversy, which was briefly mentioned in the introduction and which will now be discussed.

Since the first detailed description of Kuznetsk and related Siberian floras in 1879, by Schmalhausen, the *Annularia* remains of northern Asia have been mixed with the detached leaves of the middle-Mesozoic *Pityophyllum nordenskioldi* or *P. longifolia,* which were erroneously supposed to come from the same coal-bearing formation. The presence in the collection from Kuznetsk basin of a considerable number of typical Jurassic forms was regarded by Schmalhausen as evidence that all fossil plants collected in the coal-bearing deposits of this basin belong to Jura. This belief led him to a further erroneous conclusion that the fragmentary *Pityophyllum* leaves are merely detached and broken segments of the star-shaped whorls, which we now know to be Upper Palezoic *Annularia* foliage. Schmalhausen reasoned, furthermore, that inasmuch as these star-shaped whorls belong, as he thought, to jurassic, and as *Annularia* is not known to survive into this age, they must represent a new kind of Jurassic plant, and he introduced for these remains a new generic name *Cyclopitys,* a supposed peculiar middle-Mesozoic conifer with star-like arrangement of leaves in the whorls. He believed that he discovered how *Pityophyllum* leaves have been attached and consequently he extended his generic name to the Jurassic *Pityophyllum* leaves which were formerly described by Heer, from eastern Siberia, and accepted the specific name *nordenskioldi* Heer for both true *Pityophyllum* leaves and for *Annularia* foliage of Kuznetsk basin.

Unfortunately, neither Zeiller nor later Zalessky corrected the mistake originally made by Schmalhausen, for they did not separate the Jurassic flora of the Kuznetsk basin from the Upper Paleozoic vegetation of the same area, and in particular did not separate Jurassic *Pityophyllum* from Upper Paleozoic *Annularia.* All these paleobotanists (Schmalhausen, Zeiller and Zalessky) unanimously rejected the suggestion made by Kosmovsky (*8*) that the flora of the Kuznetsk basin has been probably collected from both Upper Palcozoic and Mesozoic beds. It is true that in this they were

supported by many other leading geologists and palcontologists, but at the same time they could not come to any agreement between themselves as to the exact age of the supposedly sole coal-bearing and plant-bearing formation of the Kuznetsk basin. Schmalhausen persisted in placing it in the Jurassic, Zeiller and Zalessky uncompromisingly referred it to the Permian and rather to the Lower Permian, while at the same time Tschernyschew, Thomas and other paleozoölogists refused to consider these deposits of any later age than Upper Carboniferous (*Pennsylvanian*). None of these paleontologists, however, ever himself collected in the Kuznetsk basin, and they all based their opinions on the study of fossils collected by various explorers who personally visited this area but did not attempt to study the fossil material which they gathered.

In regard to the particular mixture of leaves which were described by Schmalhausen as *Cyclopitys nordenskioldi* (Heer), Zeiller expressed an opinion that they resemble very much *Annularia stellata* of the Stephanian and Permian of Europe (*37*, p. 888). This opinion was formerly shared by Zalessky (*34*, pp. 7 and 28, footnotes), but later he changed his view and referred the whole lot of the remains in question to *Phyllotheca stschurowskii* Schmalhausen (*35*). By doing so he unfortunately mixed the already mixed two species with one more form with which they were never classified before, either by Schmalhausen, by Zeiller or by any other paleobotanists, many of whom justly compared *Phyllotheca stschurowskii* of Siberia with *Phyllotheca robusta* from Lower Gondwana of India (*4*, p. 69, *36*, p. 472, *1*, p. 26).

In 1915 the writer studied some exposures of the coal-bearing formations in the Kuznetsk basin, collected the various floras and made a preliminary study of his collection. In 1922, after a comparative study of the Permian, Upper Triassic and Jurassic coal-bearing formations and their flora in the Russian Far East he published a conclusion that besides the Upper Paleozoic coals, with typical Upper Paleozoic flora, there exist in the Kuznetsk basin coal-bearing beds with typical Mesozoic flora (*2*, pp. 64-68). In 1926 the writer published a list of fossil plants of the Kuznetsk basin which are associated on the same slabs in the old collections: These indicate a middle Mesozoic, most probably Liassic, age (*3*, footnotes on pp. 304, 305).

In the last three years several geologists and paleontologists made independent observations and collected fossil floras in various parts of the Kuznetsk basin, and all came to the same conclusion that

there actually exists a separate younger coal-bearing formation in this basin which overlies the coal-bearing Upper Paleozoic beds with unconformity and which contain a typical Jurassic assemblage of plant remains. The most extensive observations and most complete collections were made by Miss M. F. Neuburg, who referred these younger beds to the Liassic (*14*, p. 339), thus confirming the writer's opinion as to the age of the flora based on the study of the earlier descriptions and illustrations.

Among other authors who recently collected Jurassic flora or expressed their belief that there is a Jurassic coal-bearing formation in the Kuznetsk basin besides the Upper Paleozoic coal-bearing beds are Shorokhov (*29*, p. 7), Fomitchev (*5*, pp. 60-63), Obrutschew (*15*, pp. 303-305), Kryshtofovich (*9*, pp. 566-569), and others.

In view of all these new data on the stratigraphy and palcobotany of the coal-bearing deposits of the Kuznetsk basin there is hardly any need to discuss again the formerly rejected possibility of the presence of both Upper Paleozoic and Mesozoic floras in the Kuznetsk basin in order to explain the queer mixture of older and newer types of plants collected in the basin, because now the presence of separate Paleozoic and Mesozoic coal-bearing and plant-bearing formations in this area is no more a hypothesis, but a well-established fact. However, it remains still desirable and important to explain why the Mesozoic *Pityophyllum* leaves have been so hard to separate from the whorls of *Annularia* foliage and why these different remains have been classified together for such a long time.

The Mesozoic *Pityophyllum* leaves are about the same size and of the same linear shape as the most common Paleozoic *Annularia* leaves of *stellata, inflata, radiata* and related types. They also are gradually contracting toward the apex, which is bluntly or acutely rounded, thus somewhat resembling some *Annularia* leaves with poorly developed or broken mucro. The *Pityophyllum* leaves are, furthermore, uninerved and have a distinct fine striation of the lamina, being in these respects again comparable to *Annularia* leaves. However, the *Pityophyllum* leaves possess an interesting and characteristic combination of both longitudinal and transverse striations which makes them unlike the leaves of *Annularia*, which have only one kind of striation for a given species. The longitudinal striation of *Pityophyllum* leaves is very regular, straight and dense, as the writer observed it on many leaves of this genus from the Upper Triassic and Jurassic of Russian Far East. According to his observations on *Pityophyllum longifolium* leaves of this region the

longitudinal striæ are very fine and dense, there being about 30 striæ per 1 mm. of width of the lamina. In the thin ridges between these striæ there can be seen regularly spaced transverse depressions. These depressions most probably separate the neighboring cells of the longitudinal rows and the whole longitudinal striation apparently represents a cellular structure either of the epidermis or of hypodermal tissue. The longitudinal striation is so delicate that ordinarily it is only partly preserved on the leaves or is not preserved at all. Contrary to this the transverse striation on these leaves can be nearly always observed. It is comparatively coarse and is of entirely different nature. The transverse striæ are not quite straight, but are always somewhat wavy, and the neighboring striæ are occasionally connected. They are not quite regularly spaced one from another, and therefore they cannot be conveniently counted per given space. In fact they are mere fine transverse wrinkles of the lamina as was already concluded by Seward (*25*, p. 36), who pointed out the presence of similar type of wrinkling on the herbarian specimens of living Abietineæ and explained that it is "probably produced by contraction or drying" (*28*, p. 379). The wrinkles of this type are clearly seen on the much-enlarged photograph of *Pityophyllum nordenskioldi* on plate XXXVIII, figure 2, lower, of Zalessky's Atlas (*35*). (The leaf, which is erroneously referred by Zalessky to *Phyllotheca stschurowskii*, is reproduced on plate XVI, figure 2 of this paper.)

The leaves of *Annularia zalesskii* type of whorls from the Upper Paleozoic of the Kuznetsk basin, as was described, possess only transverse or, strictly speaking, slightly and symmetrically oblique featherlike striation. This was observed and correctly shown by Schmalhausen, who, however, did not notice the difference in the character of this striation and of the wrinkling of *Pityophyllum* leaves. The featherlike striation of *Annularia zalesskii* leaves is regular and the striæ can be counted per given space. It is important to point out that the lamina of *A. zalesskii* leaves has no longitudinal striation at all.

Contrary to this, the leaves of *Phyllotheca stschurowskii* Schmalhausen, which Zalessky mixed with *Annularia* and *Pityophyllum* leaves, have only longitudinal striation and have no transverse or featherlike striation. Furthermore, longitudinal striation of *Phyllotheca stschurowskii* leaves is considerably less dense than longitudinal striation of *Pityophyllum* leaves. There are only about 5

striæ per 1 mm. of width of the lamina in these leaves, which is at least two or three times less than the number of longitudinal striæ on *Pityophyllum* leaves from Kuznetsk basin, as far as one can count them on the best-preserved portions of the leaf of the much enlarged photograph, plate XXXVIII, figure 2, upper, of Zalessky's Atlas (*35*). Another distinguishing feature of *Phyllotheca stschurowskii* leaves is the character of their median vein, which in this species appears as a not very prominent dark line ("Schwarzeren Streifen" after Schmalhausen), while in both *Annularia zalesskii* and *Pityophyllum nordenskioldi* leaves the median vein appears as a very prominent rib not darker and often distinctly lighter than the rest of the lamina.

The main characteristic features for recognition of *Annularia zalesskii*, *Phyllotheca stschurowskii* and *Pityophyllum nordenskioldi* leaves in mixed collections are summarized in the key table II on page 141.

Annularia zalesskii and *Phyllotheca stschurowskii* are found in the Kuznetsk basin in association with other Upper Paleozoic fossil plants, while *Pityophyllum nordenskioldi* is invariably found in association with Jurassic forms. The following is the list of figures in the published papers on Kuznetsk flora in which *Phyllotheca stschurowskii* and *Pityophyllum nordenskioldi* can be recognized:

Phyllotheca stschurowskii Schmalhausen.

1879—*Phyllotheca stschurowskii* Schmalhausen. Mém. Acad. Sci St. Pétersbourg, Sér. VII, Vol. 27, No. 4, Pl. III, Fig. 2*b*, and Pl. VI, Fig. 3. Probably not Pl. IV, Fig 4*b*, and Pl. VI, Fig. 2.

1918—*Phyllotheca stschurowskii* Zalessky, M. D., Mém. Com. Géol., Nouv. Sér., Livr. 174, Pl. XXX, Figs. 1 and 1*a*. Not the rest of the numerous specimens referred to this genus and species.

Pityophyllum nordenskioldi Heer.

1869—*Annularia longifolia* Geinitz H. B., Ueber fossile Pflanzen aus der Steinkohlenformation am Altai. New Jahrb. Miner., etc., Pl. 6, Fig. 4.

1879—*Cyclopitys nordenskioldi* Schmalhausen, J. Mém. Acad. Sci. St. Pétersbourg, Sér. VII, Vol. 27, No. 4, Pl. Fig. 4*b*; Pl. 5, Figs. 2*d*, 3*b*, 6*b* and 10. Not Pl. 6, Figs. 4 and 5.

1918—*Phyllotheca stschurowskii* Zalessky, M. D. Mém. Com. Géol., Nouv. Sér., Livr. 174, Pl. 25, Figs. 1, 2 and 3; Pl. 26, Fig. 2 and 3; Pl. 27, Fig. 2; Pl. 31, Figs. 1 and 2; Pl. 38, Figs. 1, 2, 3, 4, 5 and 7; Pl. 39; Pl. 48, Fig. 5; Pl. 49, Fig. 2. Not Pl. 15, Fig. 6; Pl. 24, Figs. 1, 3, 4, 5 and 6; Pl. 25, Figs. 5, 6, 7 and 7*a*; Pl. 26, Figs. 4, 4*a*; Pl. 30, Figs. 1, 1*a*; Pl. 53, Figs. 1, 1*a*, 7 and 7*a*.

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EXPLANATION OF PLATES.

PLATE XII.

Carpannularia americana Elias.

COTYPE.

Fragment of a branch with mature sterile whorls. × ⅓. From near Clinton, Mo. Coll. Cal. Acad. Sci.

PLATE XII.

PLATE XIII.

Carpannularia americana Elias.

COTYPE.

FIG. 1*a*. Portion of a large branch with hairy appendages taking place of some of the normal leaves of the central axis. Featherlike structure is shown only on a few selected normal leaves. $\times 1\frac{1}{3}$. From near Clinton, Mo.

FIG. 1*b*. Detail of the same branch showing the structure of a selected hairy appendage. $\times 2\frac{1}{2}$.

FIG. 2. Partly opened whorl. Probably from Mazon creek, Ill. $\times 1\frac{1}{3}$. Coll. Leland Stanford Jr. Univ.

PLATE XIII.

PLATE XIV.

Carpannularia americana Elias.

COTYPE.

FIG. 1*a*. Somewhat generalized sketch to show featherlike structure of a leaf. × 2½. From near Clinton, Mo. Coll. Cal. Acad. Sci.

FIG. 1*b*. Detail of a leaf of the specimen Pl. 1, to show form and arrangement of "hairs." × 16. From near Clinton, Mo. Coll. Cal. Acad. Sci.

FIG. 1*c*. Detail of somewhat macerated leaf of the specimen Pl. XII. × 13. From near Clinton, Mo. Coll. Cal. Acad. Sci.

Annularia stellata (Schlotheim).

TOPOTYPE.

FIG. 2*a*. Somewhat generalized sketch to show the shape and lateral grooves of a leaf. × 3. From Manebach, Thüringen.

FIG. 2*b*. Portions of same leaf to show grooves and orientation of striation. Somewhat generalized. × 6.

FIG. 2*c*. Detail of same leaf to show the character of striæ between the grooves. × 20.

Carpannularia americana Elias.

HOLOTYPE.

FIG. 3*a*. Seed-bearing branch. A, irregularly rounded, brownish body. B, leaves with abnormal structure. × 1⅓. From near Clinton, Mo. Coll. Cal. Acad. Sci.

FIG. 3*b*. Oval brownish bodies scattered around seed-bearing branch. × 1⅓.

FIG. 3*c*. The lowermost seed of Pl. XIV, Fig. 3*a* and Pl. XV, Fig. 1. × 6.

COTYPE.

FIG. 4. Fragment of a lower portion of a branch with hairy appendages at the nodes of the central axis. × 1⅓. From near Clinton, Mo. Coll. Cal. Acad. Sci.

PLATE XIV.

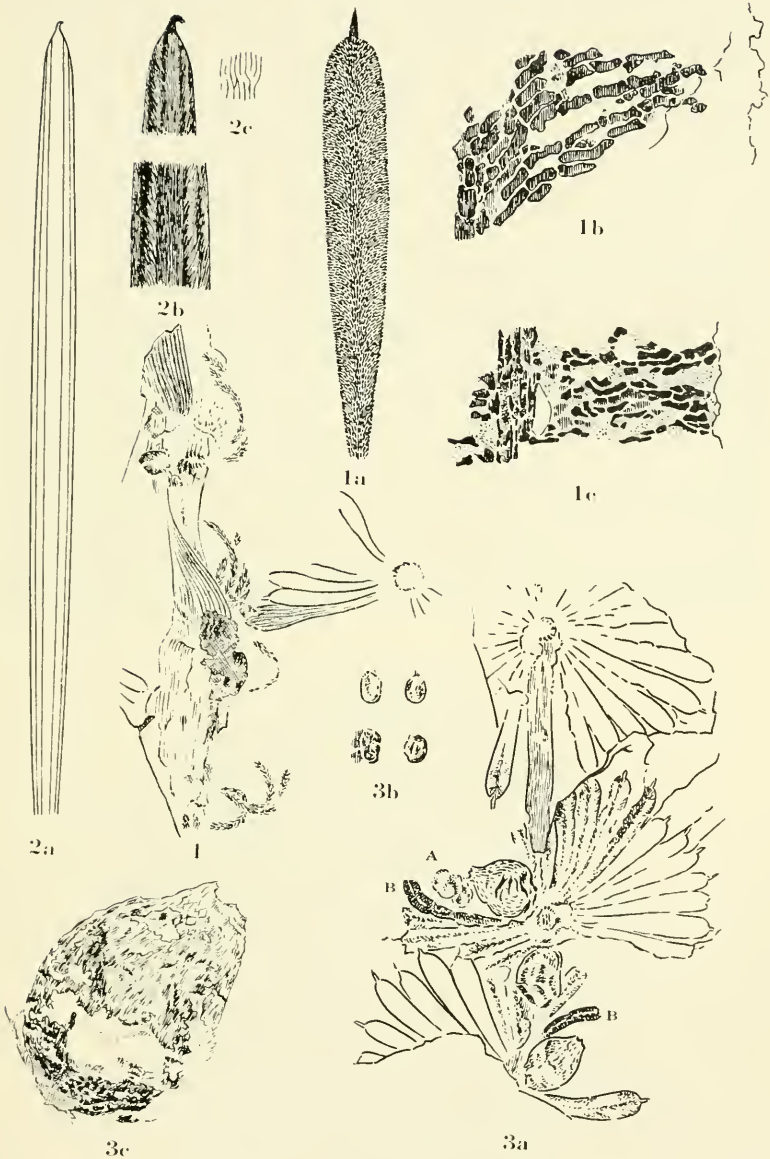


PLATE XV.

Carpannularia americana Elias.

HOLOTYPE.

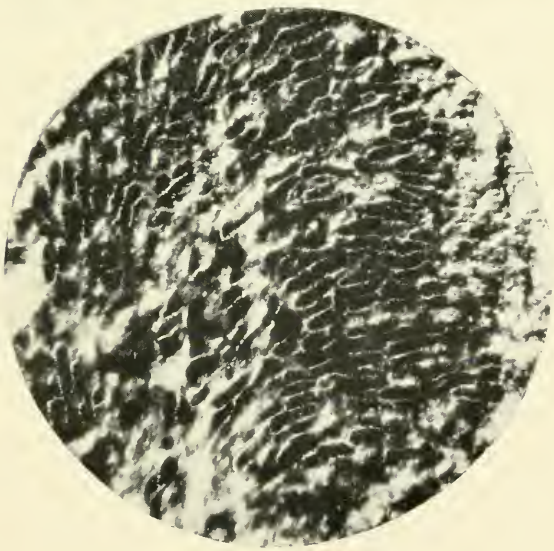
FIG. 1. Detail of the seed-bearing branch of Pl. XIV, Fig. 3*a*. ×3. From near Clinton, Mo. Coll. Cal. Acad. Sci.

COTYPE.

FIG. 2. Detail to show form and arrangement of hairs on a leaf of Pl. XII. ×18. From near Clinton, Mo. Coll. Cal. Acad. Sci.

PLATE XV.

1



2

PLATE XVI.

Annularia zalesskii Elias.

HOLOTYPE.

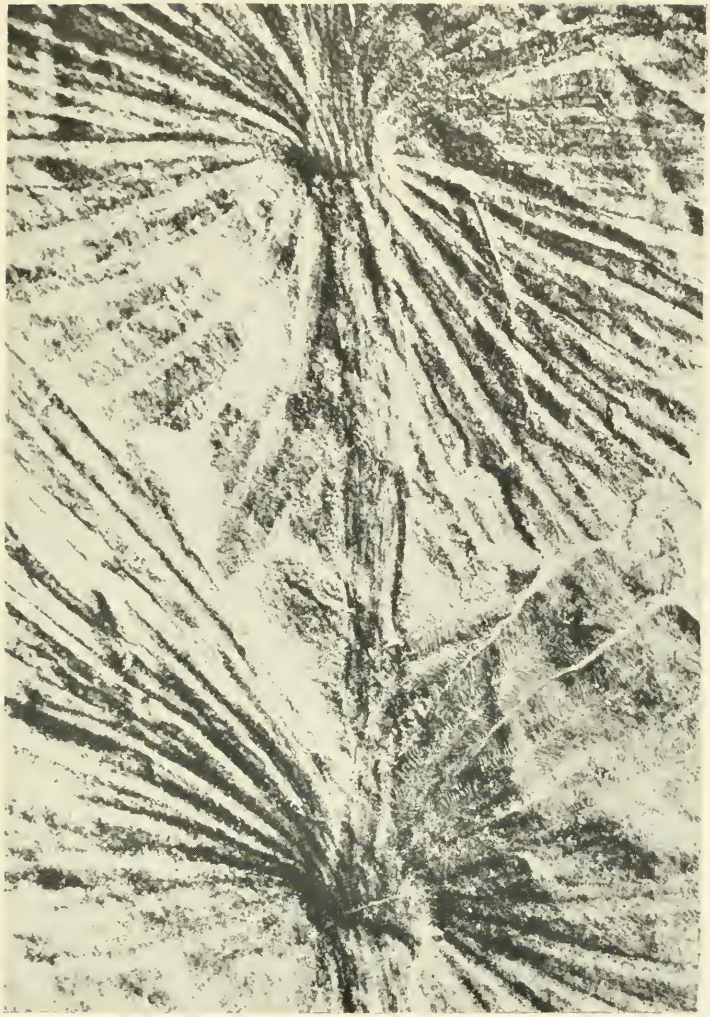
FIG. 1. Portion of a branch with distinct striation of leaves. ×5. Bachatski collieries, Kuznetsk basin, Siberia. After Zalessky.

Pityophyllum nordenskiöldi (Heer).

FIG. 2. Portion of a leaf to show transverse wrinkling. × abt. 10. Village Afonino, Kuznetsk basin, Siberia. After Zalessky.

NOTE.—In few places the fine striation is slightly retouched by the writer.

PLATE XVI.



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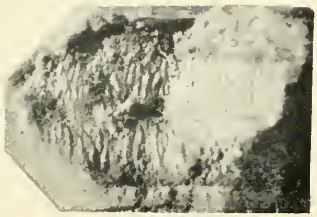

2

THE UNIVERSITY OF KANSAS
SCIENCE BULLETIN

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On the Synthesis of Certain Thioureas, Thiazolidines and Thiazanes.

F. B. DAINS, ERNEST J. JOSS and F. E. STUBBS.

THIS is a chapter in an investigation that necessitated the synthesis of certain heterocyclic compounds of known structure.

It has been long known that when α-β-diphenyl thiourea was heated with ethylene dibromide, the resulting basic product was 2-phenylimino-3-phenyl-thiazolidine, $SC(NC_6H_5)NC_6H_5CH_2CH_2$.

If the two groups in the thiourea are unlike as in α-phenyl-β-naphthyl-thiourea, two different products might be and actually are formed, viz., 2-phenylimino-3-naphthyl and 2-naphthylimino-3-phenyl-thiazolidine. In addition, if instead of the simple ethylene dibromide, propylene dibromide, $CH_2BrCHBrCH_3$, is allowed to react with the α-phenyl-β-naphthyl thiourea, there is a possibility of having a methyl group in either position 4 or 5, depending upon its mode of attack.

To illustrate with a simpler case, if the enol SH group in thiocarbanilide combined first with the CH_2Br group of the propylene dibromide, a thiazolidine would be formed with the methyl group in position 4, while if the CHBr proved to be the more reactive, the 5-methyl-thiazolidine would result. In fact the latter seems to be the actual mechanism of the reaction, since the product obtained was 2-phenylimino-3-phenyl-5-methyl-thiazolidine, $S\text{-}C(NC_6H_5)NC_6H_5CH_2CHCH_3$. To ascertain, then, what really is formed by the interaction of propylene dibromide upon the di-substituted thioureas, it is necessary to synthesize for comparison ring compounds of known structure. The following paper is a record of certain preliminary results in the investigation.

EXPERIMENTAL.

Preparation of α-Anilino-β-Propanol,

$C_6H_5NHCH_2CHOH.CH_3$.

A mixture of aniline (2 mols) and 89 per cent propylene chlorohydrin (1 mol) was heated under a reflux condenser in an oil bath at 125-30° for eight hours. The product was then made alkaline and steam distilled to remove the extra mole of aniline added to take up the hydrogen chloride freed in the reaction. The residue in the flask was extracted with ether, dried over potassium carbonate and distilled in vacuo. The fraction boiling between 195-200° at 110 mm. was collected as a light yellow oil which became red on standing.

α-β-Diphenyl-α-Propanol-2-Thiourea,

$C_6H_5NHCSN(C_6H_5)CH_2CHOHCH_3$.

When the phenyl amino-propanol was treated with phenyl isothiocyanate a thick gum was formed that failed to crystallize after two months' standing. That it was the thiourea was proven, however, by its chemical behavior, since on treatment with concentrated hydrochloric acid the ring closed, yielding the 2-phenylimino-3-phenyl-5-methyl-thiazolidine (m. p. 98°).

Anal. Calcd. for $C_{16}H_{16}N_2S$: N. 10.45. Found: N. 10.62, 10.71.

The same compound had been obtained previously by the action of acid upon α-β-diphenyl-α-allyl-thiourea. (1)

ACTION OF ACETYL CHLORIDE.

When the above thiourea in benzene solution is treated with acetyl chloride, ring closure occurs with the formation of the thiazolidine (m. p. 98°) and not an acetyl substitution product. Benzoyl chloride in the presence of pyridine gave no basic compounds but only impure gummy products.

α-β-Diphenyl-α-Propanol-2-γ-Methyl Thiourea,

$C_6H_5NC(SCH_3)N(C_6H_5)CH_2CHOHCH_3$.

Heated with methyl iodide in methyl alcohol solution, the thiourea shows the usual behavior and forms a basic thiomethyl ether. This separated as an oil on neutralizing the solution, but on long standing separated in white crystals melting at 83-4°.

Anal. Calcd. for $C_{17}H_{20}N_2OS$: N. 9.34. Found: N. 9.43, 9.65. The perchlorate salt melts at 184-5°.

ρ-Tolylamino-Propanol-2,

$C_7H_7NHCH_2CHOHCH_3$.

A mixture of ρ-toluidine (107 gms.) and 40 per cent propylene chlorohydrin (125 gms.) was heated in a flask fitted with a reflux condenser in an oil bath at 125-30° for six hours. The mixture was then made alkaline and steam distilled to remove the excess amine. The oily residue in the flask, which solidified on standing, recrystallized from alcohol in flakes which melted at 76°. It is easily soluble in alcohol, ether or benzene. A 60 per cent yield was obtained.

Anal. Calcd. for $C_{10}H_{17}NO$: N. 8.49. Found: N. 8.29, 8.19.

α-Phenyl-β-ρ-Tolyl-β-Propanol-2-Thiourea,

$C_6H_5NHCSN(C_7H_7)CH_2CHOHCH_3$.

Molar quantities of the amino-propanol and phenyl isothiocyanate were dissolved in benzene. Evaporation of the solvent left an oil which separated from alcohol in white crystals melting at 84°.

Anal. Calcd. for $C_{17}H_{20}N_2OS$: N. 9.33. Found: N. 9.13, 9.16.

2-Phenylimino-3-ρ-Tolyl-5-Methyl-Thiazolidine,

$S.C(NC_6H_5)NC_7H_7CH_2CH.CH_3$.

The ring is closed on heating the thiourea with hydrochloric acid. The acid solution is diluted with water, filtered if necessary and then neutralized. The base, which is readily soluble in organic solvents, crystallized from alcohol in long white needles melting at 74°.

Anal. Calcd. for $C_{17}H_{18}N_2S$: N. 9.93. Found: N. 9.86, 9.85. The picrate melts at 159°, and the perchlorate at 127°.

Anal. Calcd. for $C_{17}H_{18}N_2S.HClO_4$: N. 7.32. Found: 7.13.

α-Tolyl-β-ρ-Tolyl-β-Propanol-2-Thiourea,

$C_7H_7NHCSN(C_7H_7)CH_2CHOHCH_3$.

The thiourea from ρ-tolyl mustard oil and ρ-tolylamino-propanol crystallized from alcohol in white needles which melted at 89°. It is soluble in the usual organic solvents.

Anal. Calcd. for $C_{18}H_{22}N_2OS$: N. 8.92. Found: N. 8.67, 8.79.

2-ρ-Tolylimino-3-ρ-Tolyl-5-Methyl-Thiazolidine,

$SC(NC_7H_7)NC_7H_7CH_2CHCH_3$.

The base formed by heating the thiourea with hydrochloric acid is a noncrystallizable oil. Its picrate, however, which crystallized from alcohol in long yellow needles, melted at 144°. Using the

modified process of Phelps and Doubt, the analysis gave the following figures:

Anal. Calcd. for $C_{18}H_{20}N_2SC_6H_3O_7N_3$: N. 13.33. Found: 13.30, 13.19.

This same thiazolidine has been made previously from di-*p*-tolyl-allyl thiourea. (2)

α-p-Tolyl-β-Phenyl-β-Propanol-2-Thiourea.

When the phenyl-amino-propanol was treated with *p*-tolyl isothiocyanate the corresponding thiourea was formed as a gummy product which could not be obtained in a crystalline form. It was converted into the basic thiazolidine with acid.

p-Tolylimino-3-Phenyl-5-Methyl-Thiazolidine was also an oil, but it was identified by converting it into its picrate, which melted at 126°.

Anal. Calcd. for $C_{17}H_{18}N_2S.C_6H_3O_7N_3$: N. 13.65. Found: 13.61, 13.63.

Efforts to synthesize this same base by heating phenyl-*p*-tolyl thiourea with propylene dibromide were unsuccessful.

α-Phenyl-β-Propanol-β-p-Tolyl Thiourea,

$C_6H_5N(CH_2CHOHCH_3)CSNHC_7H_7$.

The product from *p*-tolyl mustard oil and the anilino propanol is a gum which was converted directly into the thiazolidine with acid or with acetyl chloride.

2-p-Tolylimino-3-Phenyl-5-Methyl-Thiazolidine, after purification from alcohol, melted at 105°. It has been obtained previously as an oil when *α*-tolyl-*β*-phenyl-*β*-allyl thiourea was treated with acid. (2)

p-Bromophenyl-amino-Propanol-2,

$Br.C_6H_4NHCH_2CHOHCH_3$.

Efforts to synthesize this by the action of propylene chlorohydrin on *p*-bromo-aniline in the presence of quinoline were not very successful, since the reaction product decomposed on distillation even under reduced pressure. Only a small amount of material was isolated, which melted at 82° and gave results on analysis for the bromo-anilino propanol.

Anal. Calcd. for $C_9H_{12}BrNO$: N. 6.09. Found: N. 6.29, 6.05.

Better yields were obtained when a mixture of *p*-bromo-aniline and propylene oxide was allowed to stand in a stoppered bottle. The product obtained tends to remain an oil and was used in that condition.

α-Phenyl-β-ρ-Bromophenyl-β-Propanol-2-Thiourea,

$C_6H_5NHCSN(C_6H_4Br)CH_2CHOHCH_3$.

This results from the interaction of phenyl-isothiocyanate and the bromophenylamino propanol. The white crystals from alcohol melt at 135°.

Anal. Calcd. for $C_{16}H_{17}BrN_2OS$: N. 7.67. Found: N. 7.70, 7.86.

Heating the thiourea with acid gave an oily thiazolidine, resembling the product obtained from propylene dibromide and phenyl-bromophenyl thiourea.

PREPARATION OF THE ISOMERIC THIOUREA AND THIAZOLIDINE.

α-ρ-Bromophenyl-β-Phenyl-β-Propanol-2-Thiourea,

$Br.C_6H_4NHCSN(C_6H_5)CH_2CHOHCH_3$.

Molecular proportions of the phenylamino propanol and ρ-bromophenyl mustard oil gave a good yield of the thiourea, melting at 138°.

Anal. Calcd. for $C_{16}H_{17}BrN_2OS$: N. 7.67. Found: N. 7.61, 7.59.

2-ρ-Bromophenylimino-3-Phenyl-5-Methyl-Thiazolidine,

$SC(NC_6H_4Br)NC_6H_5CH_2CHCH_3$.

The ring was closed on boiling the thiourea with acid. On neutralization the base precipitated as an oil, but on crystallization from ether, the product melted at 106°.

Anal. Calcd. for $C_{16}H_{15}BrN_2S$: N. 8.07. Found: N. 8.01, 7.99.

The perchlorate salt melted at 183°.

Anal. Calcd. for $C_{16}H_{15}BrN_2S.HClO_4$: N. 6.26. Found: N. 6.02, 6.20.

Derivatives of m-Xylidine (1-Amino-2-4-Dimethyl-benzene).

Heated at 125-30° with propylene chlorohydrin, it gave m-xylyl-amino-propanol-2, which boils at 220-5° at 70 mm. and melts at 130°. The thiourea with phenyl mustard oil is a gum which was converted directly into the thiazolidine by treatment with acid or with acetyl chloride.

2-phenylimino-3-m-xylyl-5-methyl-thiazolidine crystallized from alcohol in needles melting at 120°.

Anal. Calcd. for $C_{18}H_{20}N_2S$: N. 9.46. Found: N. 9.31, 9.48.

FORMATION OF OXAZOLIDINES.

2-Phenylamino-3-Phenyl-5-Methyl-Oxazolidine,

$O-C(NC_6H_5)NC_6H_5CH_2CH.CH_3$.

The preceding experiments have shown that the thiazole is formed by the loss of water between the enol SH and an OH grouping in the compound $RN\begin{matrix}/\\\\\backslash\end{matrix}\begin{matrix}CH_2CHOH.CH_3\\\\C(NR)SH\end{matrix}$ The analogous loss of H_2S would evidently yield an oxazol with oxygen closing the ring. This is readily brought about by the desulfurizing action of mercuric oxide on the thiourea in benzene solution. Thus when diphenyl propanol thiourea is heated in benzene solution with mercuric oxide mercuric sulfide is formed. From the filtrate can be isolated the oxazolidine in the form of white needles melting at 64°.

Anal. Calcd. for $C_{16}H_{16}N_2O$: N. 11.11. Found: N. 10.07, 10.92.

Desulfurization of the thiourea in the presence of aniline gave only the 64° melting product, and not the possible guanidine derivative.

In like manner were obtained the following derivatives:

2-*p*-Tolylimino-3-*p*-Tolyl-5-Methyl-Oxazolidine, from the di-*p*-tolyl propanol thiourea. The white crystals melt at 95°.

Anal. Calcd. for $C_{18}H_{20}N_2O$: N. 10.00. Found: 9.71, 9.80.

2-Phenylimino-3-*p*-Tolyl-5-Methyl-Oxazolidine, from the phenyl-*p*-tolylpropanol thiourea, has a melting point of 89°.

Anal. Calcd. for $C_{17}H_{18}N_2O$: N. 10.57. Found: N. 10.45, 10.50.

2-Phenylimino-3-m-Xylyl-5-Methyl-Oxazolidine, from the phenyl-m-xylyl propanol thiourea, crystallized from benzene in cubes and melted at 107°.

Anal. Calcd. for $C_{18}H_{20}N_2O$: N. 10.77. Found: 10.52, 10.63.

Derivatives of the Arylamino-γ-Propanols,

$RNH.CH_2CH_2CH_2OH$.

It has been shown in a previous paper (3) that the mustard oils add readily to these substituted amines, yielding thioureas from which the corresponding thiazanes are formed by the action of acids or acid chlorides. On repetition of some of the preparations, 2-phenylimino-3-phenyl thiazane was found to melt at 142° (not 139°), and the 2-*p*-tolyl-3-phenyl thiazane at 97° instead of 94°.

2-Phenylimino-3-Phenyl Oxazane,

$O\text{-}C(NC_6H_5)NC_6H_5CH_2CH_2CH_2$.

Just as the thioureas with an ethanol or propanol-2 group can be changed to oxazolidines, so desulfurization of a thiourea with the grouping $CH_2CH_2CH_2OH$ yields a six-membered ring containing oxygen. Thus on heating diphenyl-propanol-3-thiourea with mercuric oxide in benzene solution there was obtained easily and smoothly the oxazane, which crystallized from benzene in white needles melting at 157°.

Anal. Calcd. for $C_{15}H_{16}N_2O$: N. 11.11. Found: 11.15, 11.37.

SUMMARY.

(1) A number of thioureas and thiazolidines have been synthesized from the 2-propanol amines.

(2) Diphenyl propanol-3-thiourea was found to give an oxazane.

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THE UNIVERSITY OF KANSAS
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On Some Derivatives of Amino and Hydroxy-Biphenyl.

F. B. DAINS, THELMA M. ANDREWS, and MERRITT E. ROBERTS (*1*),
University of Kansas, Lawrence.

OWING to recent commercial developments, o- and p-diphenyl and (2) o- and p-dihydroxy-biphenyl have become readily accessible. (*2*) In consequence it was deemed worth while to synthesize a number of derivatives in order to determine what effect the substituting phenyl group had upon their properties.

The nomenclature is the ordinary one for biphenyl compounds, position one being at the carbons where the two rings are joined. For one ring ordinary numbers are used, in the other primed numbers. Thus p-p'-diamino-biphenyl would be also 4-4'-diamino-biphenyl, $H_2N(4)C_6H_4\ C_6H_4(4)\ NH_2$

EXPERIMENTAL.

DERIVATIVES OF p-AMINO BIPHENYL (p-XENYL AMINE) $C_6H_5.C_6H_4NH_2$: UREA AND THIOUREA COMPOUNDS

γ-PHENYL-β-p-BIPHENYL UREA, $C_6H_5NH\ CO\ NH\ C_6H_4.C_6H_5$.

Molar quantities of the amine and phenyl isocyanate were mixed in ether solution, and the resulting urea purified by recrystallization from ethanol. The difficultly soluble white crystals melted at 265°.

Anal. Calcd. for $C_{19}H_{16}N_2O$: N, 9.17. Found: 9.52.

γ-PHENYL-β-p-BIPHENYL THIOUREA, $C_6H_5NH\ CS\ NH\ C_6H_4C_6H_5$.

This is formed in almost quantitative yield when phenyl isothiocyanate is added to an alcohol solution of the amine. The white crystals are difficultly soluble in alcohol, benzene or ether, and melt at 192°.

Anal. Calcd. for $C_{19}H_{16}N_2S$: N, 9.21. Found: 9.36.

γ-o-TOLYL-β-p-BIPHENYL THIOUREA, $CH_3C_6H_4NH\ CS\ NH\ C_6H_4.C_6H_5$.

This is the product of the union of o-tolyl isothiocyanate and p-xenylamine in alcohol solution. It is difficultly soluble in organic solvents and melts at 200°.

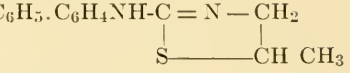
Anal. Calcd. for $C_{20}H_{18}N_2S$: N, 8.80. Found: 8.79.

γ-ALLYL-β-p-XENYL THIOUREA, $CH_5NH\ CS\ NH\ C_6H_4.C_6H_5$.

Allyl mustard oil and the amine unite readily, yielding the thiourea, which is moderately soluble in alcohol or benzene, and which melts at 204°.

Anal. Calcd. for $C_{16}H_{16}N_2S$: N, 11.11. Found: 11.19.

2-p-PHENYL-ANILINO-5-METHYL-THIAZOLIDINE,



The above allyl thiourea shows the usual behavior of such unsaturated compounds, since it slowly goes into solution in concentrated hydrochloric acid on boiling. When the filtered solution is neutralized with alkali, the substituted thiazolidine is precipitated as a white solid melting at 122°.

Anal. Calcd. for $C_{16}H_{16}N_2S$: N, 11.11. Found: 11.17.

MONO-p-BIPHENYL THIOUREA, $C_6H_5.C_6H_4NH\ CS\ NH_2$.

This is formed when a mixture of the amine hydrocloride (30 gms.) and ammonium thiocyanate (25 gms.) in 400 cc. of water is evaporated to dryness. The mass is extracted with hot water and the insoluble thiourea crystallized from hot alcohol. It then melts at 198°.

Anal. Calcd. for $C_{13}H_{12}N_2S$: N, 12.28. Found: 12.53.

THIAZOLE DERIVATIVES.

2-p-XENYL-AMINO-THIAZOLIDINE, $C_6H_5.C_6H_4NH=C=N-CH_2$ (S—CH_2)

The above thiourea was heated for several hours at 115-20° with an excess of ethylene dibromide. After distillation with steam to remove unused dibromide, the solution in the flask was filtered and made alkaline with sodium hydroxide. This precipitated a base which crystallized from benzene in blunt needles, melting at 141°.

Anal. Calcd. for $C_{15}H_{14}N_2S$: N, 11.03. Found: 11.15.

The other possible structure for this compound is that of an ethylene dithioether — $C_{12}H_9N:C(NH_2)S.CH_2CH_2S.C(NH_2)N-C_{12}H_9$—which has a nitrogen content of 11.62. Such a dithioether was obtained by Bertram (*3*) from monophenyl thiourea and ethylene dibromide, but the analysis and the fact that methyl-phenyl thiourea heated with ethylene dibromide yields both the phenyl thiazolidine and the dithioether is in favor of the ring structure for the xenyl derivative.(*4*)

2-p-XENYL-AMINO-4-THIAZOLIDONE, $C_6H_5.C_6H_4NH-C(S-CH_2)=N-CO$

The following procedure gave the best yields in the preparation of this heterocyclic compound: p-xenyl thiourea (30 gms.); ethyl chloroacetate (20 gms.), and pyridine (10 gms.) were heated in alcohol solution. The resulting difficulty soluble thiazolidone melted at 244° after purification.

Anal. Calcd. for $C_{15}H_{12}N_2OS$: N, 10.40. Found: 10.23, 10.41.

2-p-XENYL-AMINO-5-BENZAL-4-THIAZOLIDONE,

$p.C_{12}H_9NH.C(S-C:CHC_6H_5)=N-CO$

The thiazolidone shows the usual behavior of this type of compound. Thus warmed in alcohol solution with benzaldehyde and a few drops of sodium hydroxide, a very difficultly soluble yellow benzal derivative was formed which melted above 255°.

Anal. Calcd. for $C_{22}H_{16}N_2OS$: N, 7.86. Found: 7.94.

The thiazolidone dissolved in hot sodium hydroxide and on cooling a sodium salt crystallized out.

2-p-XENYL-2-p-NITROBENZYL-AMINO-4-THIAZOLIDONE,

$p.C_{12}H_9N(CH_2C_6H_4NO_2)-C(S-CH_2)=N-CO$

The sodium salt reacted readily with p-nitrobenzyl chloride in alcohol solution at room temperature, giving the nitrogen benzyl ether at position 2, which crystallized from alcohol in orange-colored needles, melting at 215°.

Anal. Calcd. for $C_{22}H_{18}N_3O_3S$: N, 10.39. Found: 10.04.

2-p-XENYL-2-ETHYL-AMINO-4-THIAZOLIDONE.

The dry sodium salt was heated for twelve hours on the water bath with an excess of ethyl iodide. After distilling off the excess of ethyl iodide with steam, the oily residue was purified by solution in dilute hydrochloric acid and precipitation with alkali. Crystallized from benzene, the light yellow ether melted at 135°.

Anal. Calcd. for $C_{17}H_{17}N_2OS$: N, 9.42. Found: 9.15.

The same compound in poorer yield was obtained by the action of diethyl sulphate upon the sodium salt.

The above structure is assigned to these ethers, since other investigations in this laboratory have shown that alkyl halides react normally at position 2.

DI-p-XENYL-FORMAMIDINE, $HC(NC_{12}H_9)NH\ C_{12}H_9$.

Ethyl orthoformic ester and p-amino diphenyl were warmed at water-bath temperature for a few minutes. The solid product when purified from benzene melted at 192°.

Anal. Calcd. for $C_{25}H_{20}N_2$: N, 8.04. Found: 7.96.

DERIVATIVES OF o-PHENYL ANILINE (o-BIPHENYL AMINE).

o-BIPHENYL THIOUREA, (1) $C_6H_5.C_6H_4$ (2) $NHCSNH_2$.

This was prepared by the action of ammonium thiocyanate upon the amine hydrochloride in aqueous solution. The white crystals from alcohol melted at 180°.

Anal. Calcd. for $C_{13}H_{12}N_2S$: N, 12.28. Found: 12.48.

ACTION OF ETHYLENE DIBROMIDE.

2-o-BIPHENYL-AMINO-THIAZOLIDINE, $C_6H_5.C_6H_4NHC{=}N{-}CH_2$ (with $S{-}CH_2$)

This base was formed when the thiourea and ethylene dibromide were refluxed for nine hours. The white crystals from benzene had a melting point of 158°.

Anal. Calcd. for $C_{15}H_{14}N_2S$: N, 11.03. Found: 10.80, 11.10.

It will be noted that the nitrogen determination corresponds more closely to the ring structure than to the open chain dithioethylene ether (N, 11.62).

ACTION OF TRIMETHYLENE DIBROMIDE.

The mono-biphenyl thiourea and the dibromide were heated at 115° for one and one-half hours. From the reaction mixture in the flask on neutralizing with alkali was isolated a basic mixture. The portion soluble in carbon tetrachloride in the cold is nearly insoluble in cold benzene, but on crystallizing from a mixture of benzene and alcohol it formed large white needles which contained bromine and melted at 97°.

Anal. Calcd. for $C_{16}H_{17}BrN_2S$: N, 8.03. Found: 8.09, 8.31.

This analysis corresponds closely to that required for the omega-bromotrimethylene thioether of the urea,

$$C_{12}H_9N{:}C(NH_2)SCH_2CH_2CH_2Br,$$

the compound that normally would be first formed from the dibromide and the thiourea.

The above basic mixture also contained a white solid insoluble in the cold carbon tetrachloride and melting at 241°. It gave tests for bromine and for nitrogen (8.08, 8.17), but its constitution has not been definitely determined.

2-o-BIPHENYL-AMINO-4-THIAZOLIDONE, $C_6H_5C_6H_4NH\ C{=}N{-}CO$ (S—CH_2)

A mixture of o-biphenyl thiourea, ethyl chloroacetate, pyridine, and alcohol was heated on the water bath for two hours. It was then steam distilled, leaving a residue in the flask which solidified to a brittle mass. This was dissolved in benzene, boiled with charcoal and allowed to crystallize slowly; the needles melted at 141°.

Anal. Calcd. for $C_{15}H_{12}ON_2S$: N, 10.40. Found: 10.33.

This thiazolidone behaves in a wholly analogous manner to the corresponding p-phenyl aniline derivative as is shown in the following preparations:

2-o-BIPHENYL-AMINO-5-BENZAL-4-THIAZOLIDONE.

An alcoholic solution of the thiazolidone and benzaldehyde with a few drops of sodium hydroxide was allowed to stand for a week. It was then distilled with steam and the residue in the flask crystallized from benzene. The fine white needles melted at 216°.

Anal. Calcd. for $C_{22}H_{16}N_2OS$: N, 7.86. Found: 7.70.

2-o-BIPHENYL-2-(p-NITROBENZYL)AMINO-4-THIAZOLIDONE.

This is formed by the action of p-nitrobenzyl chloride on the sodium salt of the thiazolidone. It is a yellow solid melting at 255°.

Anal. Calcd. for $C_{22}H_{18}N_3O_3S$: N, 10.39. Found: 10.06.

2-o-BIPHENYL-2-BENZYL-AMINO-4-THIAZOLIDONE

From the sodium salt and benzyl chloride, has a melting point of 181°.

Anal. Calcd. for $C_{22}H_{19}N_2OS$: N, 7.79. Found: 7.67.

2-o-BIPHENYL-2-ETHYL-AMINO-4-THIAZOLIDONE.

This was synthesized from the sodium salt both by the action of ethyl iodide and of diethyl sulphate. The flat crystals from benzene melted at 156°.

Anal. Calcd. for $C_{17}H_{17}N_2OS$: N, 9.42. Found: 9.50.

γ-o-TOLYL-β-o-BIPHENYL THIOUREA,

$CH_3C_6H_4NH\ CS\ NH\ C_6H_4.C_6H_5$

In alcohol solution o-tolyl isothiocyanate added with ease the biphenylamine; the resulting thiourea separated from alcohol in white crystals melting at 149°.

Anal. Calcd. for $C_{20}H_{18}N_2S$: N, 8.80. Found: 8.65.

THE PHENYLPHENOL ETHERS.

Because of the analogy with phenetol, a study has been made of the nitro and amino derivatives of p- and o-ethoxy-phenylphenol. The results indicate little difference in reactivity, but possibly a somewhat greater stability in the phenylphenol compounds.

PREPARATION OF 4-ETHOXYBIPHENYL, $C_6H_5.C_6H_4OC_2H_5$.

p-Phenylphenol (170 gms.) was dissolved in a solution of potassium hydroxide (150 gms. in 600 cc. of water). To this solution diethyl sulfate (150 gms.) was added, with constant stirring, in the course of one-half hour. To complete the reaction, the mixture was heated on a water bath for several hours. The crude ether floated on the surface as an oil, but solidified on cooling. It was separated and washed with warm water to remove the excess of potassium hydroxide and a little unchanged potassium phenolate; crystallizing from alcohol gave in 87 per cent yield, the ether melting at 74°.

NITRATION OF 4-ETHOXYBIPHENYL.

The following method, which is a modification of one used by Bell and Kenyon (*5*) with the methoxybiphenyl, gave good results. Twenty grams of the ethyl ether were dissolved in glacial acetic acid (200 cc.). To this, in the course of one-half hour, were added with constant stirring ten cc. of fuming nitric acid dissolved in 25 cc. of glacial acetic acid. To complete the reaction, the mixture was warmed at 60° for thirty minutes. When the solution was poured into water, the crude yellow nitration product was precipitated. This was washed free from acid and dried. It was then further purified as follows:

The crude nitro product was dissolved in gasoline and allowed to cool to room temperature and filtered from fraction A (m. p. 85-7°). The filtrate on cooling with ice deposited a second fraction B (m. p. 65-70°). Repeated crystallization of A, the main product, from hot alcohol gave a pure nitro compound melting at 94°.

Anal. Calcd. for $C_{14}H_{13}NO_3$: N, 5.76. Found: 5.98.

That this compound melting at 94° was the 3-nitro-4-ethoxy-biphenyl was proven by heating it with aluminum chloride at 110°. From the reaction product was isolated 3-nitro-4-hydroxybiphenyl, m. p. 66°. (*6*)

3-NITRO-4-BIPHENYL BENZOATE, $C_6H_5C_6H_3(NO_2)O.COC_6H_5$.

This was prepared by the action of benzoyl chloride on the nitrophenylphenol dissolved in sodium hydroxide. The yellow needles melted at 101°.

Anal. Calcd. for $C_{19}H_{13}NO_4$: N, 4.64. Found: 4.64.

REDUCTION OF 3-NITRO-4-ETHOXYBIPHENYL.

AZOXY DERIVATIVE.

When the nitro-ethoxybiphenyl was heated with a solution of sodium hydroxide in methyl alcohol, it was reduced and there was isolated in poor yield the difficultly soluble yellow azoxy compound melting at 196°.

Anal. Calcd. for $C_{28}H_{26}O_3N_2$: N, 6.39. Found: 6.14.

3-AMINO-4-ETHOXYBIPHENYL, (1) $C_6H_5C_6H_3NH_2$ (3)O C_2H_5 (4).

Reduction of the nitro compound with iron or tin with hydrochloric acid gave indifferent results. The method of Suter using zinc dust and calcium chloride in alcoholic solution (7) was only partially successful. However, very satisfactory results were obtained by dissolving the nitro compound (25 gms.) in warm alcohol, adding 0.1 gm. platinum black and reducing with hydrogen under forty pounds pressure with constant shaking. The reaction was complete in one and one-half hours. The product obtained on distilling off the alcohol was purified by conversion into its hydrochloric acid salt (m. p. 241°) from which the free base (m. p. 90°) was precipitated by the addition of sodium carbonate.

3-ACETAMINO-4-ETHOXYBIPHENYL, $C_6H_5C_6H_5(NHCOCH_3)OC_2H_5$.

The acetyl compound from the base and acetic anhydride crystallized from hot water in white flakes which melted at 142°.

Anal. Calcd. for $C_{16}H_{17}NO_2$: N, 5.44. Found: 5.33.

3-BENZOYL-AMINO-4-ETHOXYBIPHENYL,
$C_6H_5C_6H_3(NHCOC_6H_5)OC_2H_5$.

The product obtained by treating the base with benzoyl chloride in an alkaline solution was crystallized from alcohol. The white needles melted at 127-8°.

Anal. Calcd. for $C_{21}H_{19}NO_2$: N, 4.42. Found: 4.46.

γ-PHENYL-β-4-ETHOXY-3-BIPHENYL THIOUREA,
$C_6H_5NH\ CS\ NH\ C_6H_3C_6H_5(OC_2H_5)$.

Phenyl isothiocyanate added in the usual manner to the amine yielded the above thiourea melting at 134°.

Anal. Calcd. for $C_{21}H_{20}N_2OS$: N, 8.05. Found: 8.49.

4′-AMINO-4-ETHOXYBIPHENYL, $H_2N.C_6H_4.C_6H_4OC_2H_5$.

Earlier in this paper it was noted that the nitration of p-ethoxybiphenyl gave mainly the 3-nitro compound, but in addition an impure fraction that melted at 65-70°. When the latter was reduced with hydrogen there was isolated mainly the 3-amino-ethoxybiphenyl, but in addition a base that melted at 181°.

Anal. Calcd. for $C_{14}H_{15}ON$: N, 6.56. Found: 6.87.

The hydrochloride melts above 240° and contains 5.24 per cent N. (Calcd. 5.60).

Bell and Kenyon have shown that the nitration of p-methoxybiphenyl gave not only the 3-nitro but also some 4′-nitro-methoxybiphenyl. Hence the assumption that the 181° base has the amino group in position 4′. The amount obtained of the 181° product, 3 grams from 50 grams of the fraction melting between 65-70°, did not allow of further proof of constitution.

The 4′-amino compound was further characterized by the synthesis of its benzoyl derivative

4′-BENZOYL-AMINO-4-ETHOXY-BIPHENYL,

which crystallized from alcohol in white flakes, melting at 238°.

Anal. Calcd. for $C_{21}H_{19}O_2N$: N, 4.41. Found: 4.34.

2-ETHOXYBIPHENYL, $C_6H_5C_6H_4OC_2H_5(2)$.

o-Hydroxybiphenyl (170 gms.) was dissolved in a sodium hydroxide solution (150 gms. NaOH in 500 cc. water). To this solution was added with constant stirring in the course of one-half hour diethyl sulfate (150 gms.). To complete the reaction, the mixture was warmed on a water bath for three hours. The oil was then separated, washed with water and purified by crystallization from alcohol. The white ether melted at 34°. This has been made previously by the interaction of o-phenylphenol, sodium ethylate and ethyl iodide.(8)

5-NITRO-2-ETHOXYBIPHENYL, $C_6H_5.C_6H_3(OC_2H_5)NO_2$.

Good yields were obtained by the nitration of the 2-ethoxybiphenyl under the following conditions: The ether (20 gms.) was dissolved in glacial acetic acid (200 cc.). To this was added in the

course of one-half hour fuming nitric acid (10 cc. in 25 cc. glacial acetic acid). The mixture was then heated at 60° for thirty minutes. On pouring into cold water the nitro compound separated in yellow crystals, which were purified from alcohol, (m. p. 110°). Hill and Hale had made the compound previously by the ethylation of 5-nitro-2-hydroxybiphenyl. (*9*)

o-BIPHENYL ACETATE, $C_6H_5C_6H_4O.COCH_3$.

Honigschmidt has described this ester, but failed to give its melting point, which was found to be 65°. (*10*)

ACTION OF BROMINE ON THE ETHOXYPHENOL.

5-BROMO-2-ETHOXYBIPHENYL.

The ethyl ether is readily brominated in chloroform solution. The product obtained after recrystallization from alcohol formed white needles melting at 42°.

Anal. Calcd. for $C_{14}H_{13}OBr$: Br, 28.85. Found: 28.82.

From analogy it is assumed that the bromine enters the 5-position. Efforts to obtain the free bromo-hydroxybiphenyl by heating with aluminum chloride gave only tar.

BROMO-5-NITRO-2-ETHOXYBIPHENYL.

The nitro compound dissolved in chloroform slowly reacts with bromine and yields probably the 3-mono-bromo derivative,—light yellow needles which melt at 96°.

Anal. Calcd. for $C_{14}H_{12}BrNO_2$: N, 4.57. Found: 4.46.

5-IODO-2-ETHOXYBIPHENYL, $C_6H_5C_6H_3I(OC_2H_5)$.

Molar quantities of the ethoxybiphenyl and iodine monochloride dissolved in glacial acetic acid reacted readily on heating. The oil obtained distilled at 215-216° at 10 mm. It then solidified and after crystallization from alcohol had a melting point of 75°.

Anal. Calcd. for $C_{14}H_{13}IO$: I, 39.17. Found: 38.53.

Treatment of the 2-hydroxybiphenyl with iodine monochloride under like conditions gave a colorless oil which on ethylation yielded the above iodo ether melting at 75°.

5-NITRO-3-IODO-2-ETHOXYBIPHENYL, $C_6H_5.C_6H_2.I.NO_2.OC_2H_5$.

The nitro ether slowly reacts in hot acetic acid with iodine monochloride and there was isolated a yellow compound with the iodine probably in position 3, and which melted at 135° after crystallization from alcohol.

Anal. Calcd. for $C_{14}H_{12}INO_3$: N, 3.80. Found: 3.72.

REDUCTION OF THE NITRO-ETHER.

2-ETHOXY-5-AZOXY-BIPHENYL, $[C_6H_5.C_6H_3(OC_2H_5)]_2N_2O$.

When the nitro compound is warmed at 80° in a solution of alcohol and sodium ethylate, a rapid reaction occurs and there was isolated the yellow azoxy derivative, which after crystallization from benzene melted at 189°.

Anal. Calcd. for $C_{28}H_{26}N_2O_3$: N, 6.38. Found: 6.28.

5-AMINO-2-ETHOXY-BIPHENYL, $C_6H_5.C_6H_3(OC_2H_5).NH_2$.

The 5-nitro ether can be reduced to the amine using zinc dust and calcium chloride, but more satisfactory results were obtained with hydrogen under pressure with a platinum catalyst. It was obtained as an oil which failed to solidify at 0°. It was analyzed as the hydrochloride which melted at 215°.

Anal. Calcd. for $C_{14}H_{16}ClNO$: N, 5.62. Found: 5.63.

The acetyl derivative was made by boiling the base with acetic anhydride. When crytallized from hot water, the pale lavender flakes had a melting point of 155°.

Anal. Calcd. for $C_{16}H_{17}NO_2$: N, 5.44. Found: 5.52.

The benzoyl derivative by the Schotten-Baumann reaction melted at 204°.

Anal. Calcd. for $C_{21}H_{19}NO_2$: N, 4.41. Found: 4.47.

γ-PHENYL-β-2-ETHOXY-5-BIPHENYL THIOUREA.

The amine reacts slowly in alcohol solution with phenyl isothiocyanate giving the thiourea, which melts at 137°.

Anal. Calcd. for $C_{21}H_{20}N_2OS$: N, 8.04. Found: 8.17.

SUMMARY.

The 2- and 4-ethoxybiphenyl amines have been synthesized and illustrative derivatives of these, together with others from o- and p-amino-biphenyl, have been prepared.

(1) This paper was constructed from theses presented as partial requirements for the M. A. degree at the University of Kansas.

(2) For the ortho and para-hydroxybiphenyl we wish most heartily to thank Mr. W. J. Hale, of the Dow Chemical Company, who kindly placed at our disposal the phenols used in the investigation.

(3) Bertram, Ber. 25, 59 (1892).
(4) Dains, Brewster and others, J. Am. Ch. Soc. 47, 1987 (1925).
(5) Bell and Kenyon, J. Ch. Soc. 129, 3046 (1926).
(6) Schmidt and Schultz, Ann. 207, 347 (1881).
Raiford and Colbert, J. Am. Ch. Soc. 47, 1456 (1925).
(7) Suter, J. Am. Ch. Soc. 51, 2581 (1929).
(8) Honigschmidt, Monats. 22, 569 (1901).
(9) Hill and Hale, Am. Ch. J. 33, 10 (1905).
(10) Honigschmidt, Monats. 22, 569 (1901).

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The Effect of Temperature on the Natural Ionization of Gases in an Iron Chamber.

J. W. HAKE.

INTRODUCTION.

THE conduction of electricity through gases is generally attributed to the presence of ions. Since there are always some ions present it follows that there must be some agent at work breaking up the atoms. This ionization which exists in gases is known as natural ionization. Early experimenters thought that this was an inherent property of the gas itself. Later, however, the theory of a penetrating radiation was advanced. This theory has received so much experimental support that it is now generally accepted.

The natural ionization was first investigated by Elster and Geitel[1] and by C. T. R. Wilson.[2] The experiments of Elster and Geitel showed that, with air in a closed vessel, the rate of leak of a charged electrometer was proportional to the pressure, that the leak was independent of the voltage above a certain saturation potential, and that the rate of leak was the same for positive as for negative electricity. These results were confirmed by Wilson.

The origin of the radiation which brings about the ionization in closed vessels is of great interest. Four sources have been pointed out by various investigators: Radioactive materials in the soil; radioactive emanation in the air; impurities in the walls of the vessel; penetrating radiation, probably coming into the earth's atmosphere from all directions.

Rutherford and Cooke[3] investigated the effect of screens on natural ionization. The rate at which ions were formed was obtained by allowing an electroscope to discharge without a protecting screen.

1. Elster and Geitel: Phys. Zeits. 2, 560; 2, 116 (1900).
2. Wilson: Roy. Soc. Proc. 68, 151 (1901); 69, 277 (1902).
3. Rutherford and Cooke: Phys. Rev. 16, 183 (1902).

The electroscope was then surrounded by a lead screen 5 cm. thick, and a decrease of 30 per cent observed.

Strutt[4] found that the ionization in a closed vessel depends on the material of which the ionization chamber is constructed. Of the materials studied, lead produced the highest and zinc the lowest ionization. These results were confirmed by Wood[5] and by Campbell.[6]

J. J. Thomson suggested that every material emits and absorbs penetrating radiation capable of producing ions in a closed vessel, and that the screening effect depends on the ratio of the emission and the absorption for the material and on the thickness of the screen. Cooke found, further, that no matter how thick the lead screen the ionization could not be reduced more than 30 per cent. This led to the conclusion that there must be a very penetrating radiation from an external source.

In 1910 A. C. Eve[7] worked out a relationship between altitude and radiation, assuming that the radioactive material was distributed over the surface of the earth. This led to a series of experiments at different altitudes by Wulf,[8] Gockel,[9] Hess,[10] Kohlhoerster,[11] Millikan and Bowen,[12] and Millikan and Otis.[13] Hess explained the results of the experiments by assuming a very penetrating radiation to come from above into our atmosphere penetrating to the surface of the earth and causing part of the ionization in closed vessels.

Millikan and Cameron[14] sank an electroscope to a depth of 50 feet below the surface of the water in Muir Lake (altitude 11,800 ft.) and found that the ionization decreased from 13.3 at the surface to 3.6 ions per c. c. per second. Readings taken in Arrowhead Lake (alt. 5,100 ft.) correspond to readings taken at a depth of 6 feet deeper in Muir Lake. From a curve drawn for ionization under water Σ varies from 0.25 to 0.15 per meter of water. This corresponds to wave lengths from 0.000525 to 0.00032 A. (Computed by means of A. H. Compton's formula.) They concluded that the rays are of cosmic origin, very hard, and that they enter the earth uniformly from all directions.

4. Strutt: Phil. Mag. 5, 680 (1903).
5. Wood: Phil. Mag. 9, 550 (1905).
6. Campbell: Phil. Mag. 11, 206 (1906).
7. Eve: Phil. Mag. 21, 26 (1911).
8. Wulf: Phys. Zeits. 10, 997 (1909).
9. Gockel: Phys. Zeits. 16, 345 (1915).
10. Hess: Phys. Zeits. 12, 998 (1911); 13, 1084 (1912); 14, 610 (1913).
11. Kolhoerster: Deutch. Phys. Gessell. Verh. 16, 719 (1914).
12. Millikan and Bowen: Phys. Rev. 27, 353 (1925).
13. Millikan and Otis: Phys. Rev. 27, 645 (1926).
14. Millikan and Cameron: 28, 851 (1926); Phys. Rev. 31, 163 (1928); 31, 921 (1928).

Patterson[15] found that the ionization is proportional to pressure for low pressures, but not for pressures above 30 cm. when the vessel is large. Miss Downey [16] found the ionization nearly proportional to the pressure up to 20 atmospheres. The curves given by Fruth[17] are practically straight up to 50 atmospheres and then bend toward the pressure axis. Broxon[18] carried the pressure up to 100 atmospheres and found no saturation pressure. His curves are smooth and at all points concave toward the pressure axis.

A. Wood[19] heated the walls of the vessel and found an increase in ionization. Air drawn over tin discharged an electroscope more rapidly when the tin was heated than when the tin was cold. This increased conductivity could be removed from the air by passing it through metal tubes, proving that it consisted of ions and not of emanation.

Kunsman[20] investigated the effect of temperature on the ionization of gases by making an electroscope air-tight and immersing it in a cooling bath. The data obtained shows an increase in ionization with decrease in temperature. He concluded, however, that the apparent increase in ionization was due to an increase in conductivity over the surface of the insulation, and that the electrical conductivity of residual ionization is not caused by the molecular impact which is due to thermal agitation.

Campbell[21] found a slight increase in ionization while the temperature of the ionization chamber was being raised and a decrease while the termperature was being lowered. He suggested that this might be due to electricity induced on the electrode by very massive charged particles carried about by convection currents.

Patterson[22] heated the ionization chamber while the pressure was kept constant. He found that the ionization current increased but very little if at all. Patterson, however, allowed the gas to expand, and this brings about a decrease in density. At constant volume a decrease in density causes a decrease in ionization, due to penetrating radiation, as has been shown by a number of observers; an increase in ionization on account of thermal effect would thus be offset by a decrease in ionization because of penetrating radiation.

15. Patterson: Phil. Mag. 6, 231 (1903).
16. Downey: Phys. Rev. 16, 420 (1919).
17. Fruth: Phys. Rev. 22, 109 (1923).
18. Broxon: Phys. Rev. 27, 542 (1926).
19. Wood: Phil. Mag. 9, 550 (1905).
20. Kunsman: Phys. Rev. 16, 349 (1920).
21. Campbell: Phil. Mag. 13, 614 (1907).
22. Patterson: Phil. Mag. 6, 231 (1903).

Devik[23] heated the gas by adiabatic compression and measured the ionization at the moment of greatest compression. Antimony hydride was the only gas studied which showed any marked increase in ionization at the highest temperature obtained, which he estimated to be 900 degrees centigrade.

Kingdon[24] made an air-tight ionization chamber about which he wound a resistance wire for changing the temperature. The temperature was changed from 30 to 100 degrees centigrade at constant volume. The observed changes in ionization were very small from 30 to 80 degrees and much larger from 80 to 100 degrees.

Langevin[25] deduced a formula for the ionization that might be produced by thermal impact. This expression, however, demands that the ionization increase very rapidly with temperature, which is contrary to experimental evidence. Kingdon[26] revised the formula so as to give results which are in fair agreement with observed values.

The present problem is an investigation of the effect of temperature on the natural ionization of gases in a closed vessel. The density of the gas was kept constant while the pressure was allowed to change. The effect of pressure on the ionization at constant temperature was also investigated.

APPARATUS.

The essential parts of the apparatus are: an ionization chamber, a gold-leaf electroscope, a cooling system for the amber insulation, a device for maintaining a constant water pressure, an electrical furnace, a thermostatic control, and two thermo-couples, one for measuring the temperature of the furnace and the other for measuring the temperature of the insulation.

The ionization chamber (Fig. 1) consists of a cylindrical steel tank, 15 cm. in diameter, having a capacity of 10.06 liters. To this was fitted a cooling system, turned out of steel. A detailed drawing of this is shown in figure 2. The neck of the cooling system was about 5 inches long, with a small hole (1.3 cm.) through the center of it. The neck was made long in comparison with the diameter in order to cut down the conduction of heat. Convection currents were kept low by the small hole through the neck and further reduced by a glass plate at the upper end of the neck. The hole through the

23. Devik: Sitz. d. Heid. Akad. Wiss. 24 (1914).
24. Kingdon: Phil. Mag. 32, 396 (1916).
25. Langevin and Rey: Le Radium, 10, 142 (1913).
26. Kingdon: *loc. cit.*

glass plate was made 5 mm. in diameter. In order to allow room for the end of the amber plug and an annular tray of drying material, the hole was enlarged to 5 cm. at the upper end. Water was allowed to circulate freely through a cavity about the upper part of the neck. The lower part of this cavity was closed by a steel plate threaded onto the neck and fitted with a rubber gasket. A steel plate, 1.5 cm. thick, closed the upper end of the neck. Into this

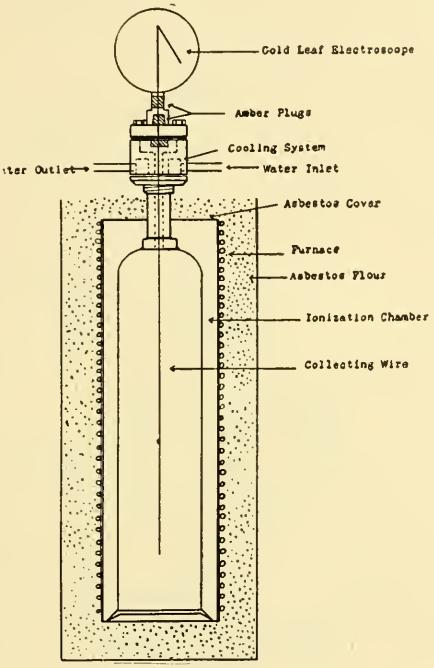

FIGURE 1.

plate was fitted an amber cone which carried the central system for collecting the charges. The metal part was made of brass, cone-shaped at one end. Both ends of this brass were turned to the same size and threaded in order that the collecting wire might be attached to either end. The steel plate is also reversible so that the plate may be used in the position shown when the tank is filled with gas. When it was desired to exhaust the tank the plate was turned over. In this way the brass cone, the amber cone, and the steel plate will always be forced together by the existing pressure, thus making an air-tight joint. The steel plate was held in place by nine machine bolts. A lead gasket made the joint between the plate and the main body air tight.

The gold-leaf electroscope was supported by a separate housing held in place by three machine bolts. In order to avoid convection currents in the electroscope as much as possible, an amber plug was fitted into the neck of the electroscope. Contact between the electroscope and the collecting system was made by means of a coiled spring of brass wire. On the inside of the housing supporting the electroscope was placed an annular tray of phosphorus pen-

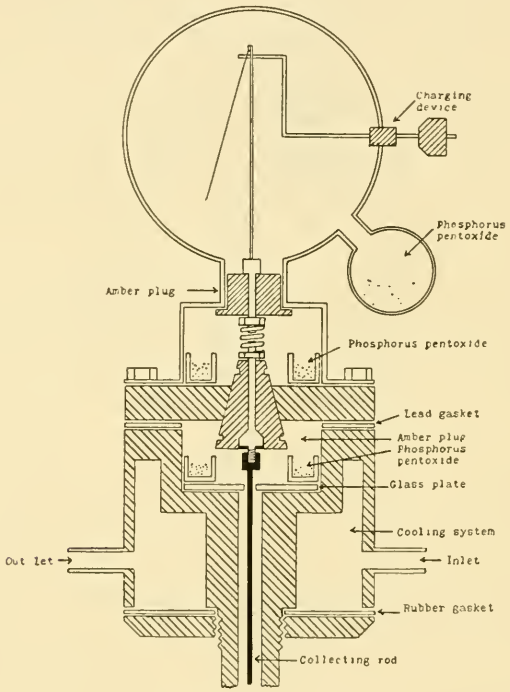

FIGURE 2.

toxide. The electroscope was also provided with a flask containing phosphorus pentoxide. A thin piece of brass was soldered onto the upper end of the leaf support. The leaf was stuck on this piece of brass, thus causing the leaf to free itself from the support up to the edge of this piece. All joints of the electroscope were coated with sealing wax and paraffin, thus making it practically air tight. The electroscope was provided with a reading microscope and to facilitate the reading a fine quartz fiber was fastened to the end of the gold leaf.

To keep the temperature of the amber constant the outlet of the

cooling system was provided with a stop cock and the intake with an overflow can the height of which could be adjusted. A boiler was also provided so that the water could be warmed when the temperature of the ionization chamber was below room temperature.

The collecting system consisted of a brass rod 3 mm. in diameter, supported by a thin Chromel wire. Chromel wire was used for the support, since it has a very low coefficient of thermal conductivity.

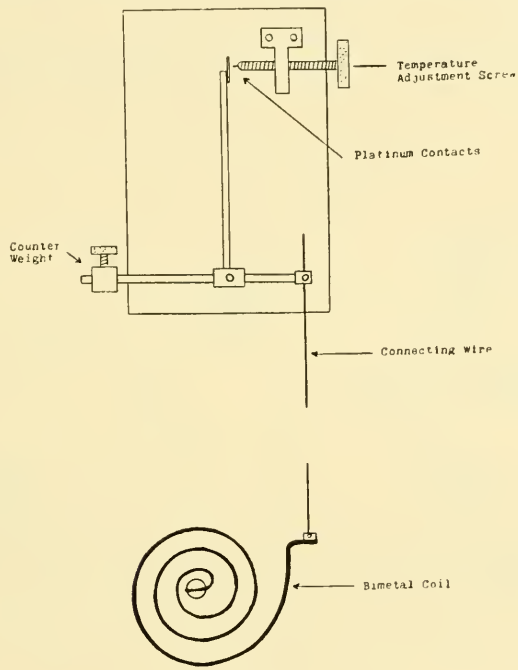

FIGURE 3.

The furnace was made of two tanks, one 8 inches in diameter and 34 inches high, the other 14 inches in diameter and 40 inches high. (Fig. 1.) The smaller tank was made of heavy sheet iron so as to make it rigid. It was covered with asbestos paper and then wound with No. 10 Chromel A wire so as to have a resistance of about 7 ohms. The wire was held in place by American Seal furnace cement, which was found to work admirably. The cement was applied only in narrow, vertical strips, thus leaving most of the wire exposed. Four such strips were found to be ample to hold the wires in place. After the cement had dried this tank was placed into the larger one, leaving 3 inches at the bottom, and the space between the two tanks

filled with asbestos flour. The ionization chamber was then placed into the furnace, an asbestos cover fitted around the neck of the cooling system, and asbestos flour added to fill the outer can. The furnace was placed on a concrete pier and firmly anchored to it. The ionization chamber was anchored to a rigid ring about the upper part of the outer can, which was in turn anchored to the pier. This was done in order to avoid any change of capacity which might be caused by tilting of the cylindrical chamber.

The temperature was controlled by means of a bimetal thermostat and a system of levers. (Fig. 3.) The platinum points opened and closed a circuit which in turn operated a switch in the main circuit.

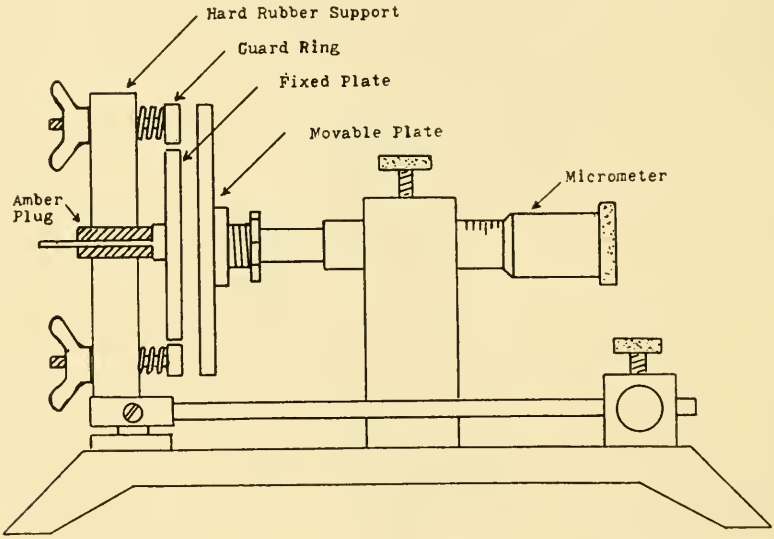

FIGURE 4.

An old magnetic control from a Johnston heating system was slightly modified and found to be exceedingly sensitive as a control switch. A shunt resistance was placed across the switch terminals in addition to a series resistance in the main circuit. It was found that by proper adjustment of the series and shunt resistances the temperature could be kept from overshooting. With a little patience the adjustment could be made to hold the temperature constant to one degree and left without attention for days.

The temperature was obtained with a Chromel-Alumel thermocouple in connection with a potentiometer. One junction was fastened to the middle of the ionization chamber while the other end

was kept in a constant temperature bath. For comparison a mercury thermometer was also placed on the inside of the furnace. A second thermocouple had one junction fastened onto the cooling system close to the amber while the other junction was kept in a constant temperature bath.

A standard parallel plate condenser of the desired range was constructed. (Fig. 4.) The central disk and guard ring are supported by hard rubber, the central disk being mounted firmly to it by means of amber insulation. The guard ring, which has an inside diameter of 5.2 cm. and an outside diameter of 7.2 cm., is mounted on a three-point adjustable support so that it can be brought into the plane of the central disk. The movable plate consists of a disk 7.2 cm. in diameter, mounted on a micrometer shaft. The support holding the micrometer is bolted firmly to the iron base. The support of the guard ring and central disk is so mounted as to allow an adjustment in declination and azimuth. By these adjustments the guard ring, central disk, and movable disk can be brought into parallelism. A contact key is fastened to the hard-rubber support and by means of it the central disk may be connected to or disconnected from the guard ring.

METHODS AND RESULTS.

The gold leaf was calibrated by means of a high-potential battery in series with a 22-volt potentiometer arrangement. Taps on the high-potential battery allowed sections to be cut out as desired. The potential was measured with a Siemens and Halske standard voltmeter. In order to avoid any error caused by a lag between the applied potential and the deflection of the gold leaf, the leaf was charged to its maximum deflection and readings taken at every ten divisions down to zero. Without allowing the leaf to discharge, the potential of the leaf was raised again by steps of ten divisions and readings taken up to the maximum. A number of observations were made in this manner and the mean used for plotting a curve. In order to obviate any error caused by the "soaking-in effect" in the amber the leaf was never allowed to discharge completely during a run. The calibration curve is shown in figure 5.

The capacity of the electroscope was obtained by means of the parallel plate condenser shown in figure 4. The leaf system was connected to the central disk, the movable plate removed to a definite distance, and the desired voltage applied with the guard ring connected to the central disk. The central disk was then dis-

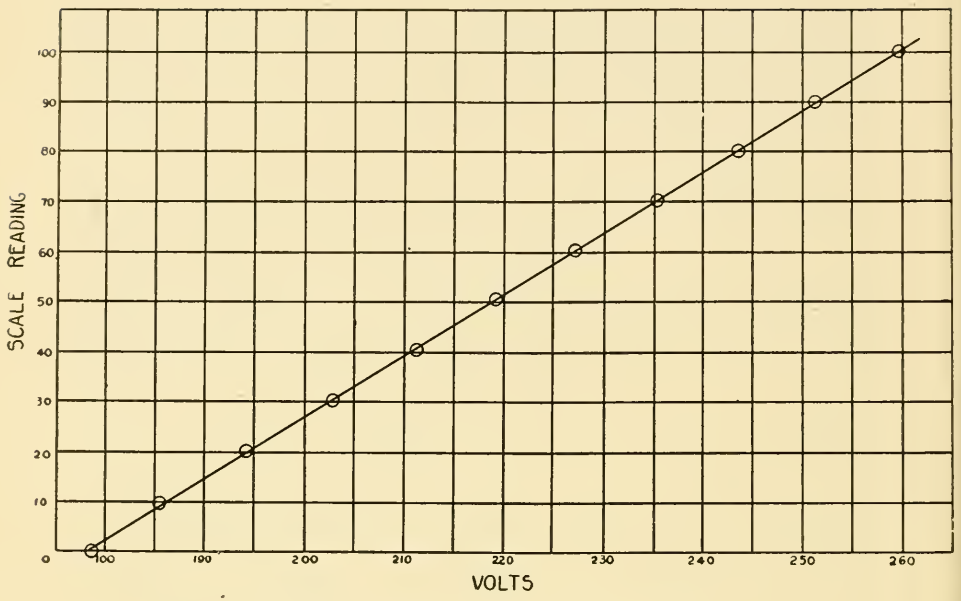

FIG. 5. Calibration curve for electroscope.

connected from the guard ring and the movable plate brought up to the central disk until the leaf had fallen to the desired potential. During this process the guard ring, which was always connected to the battery, was kept at the same potential as the leaf. This potential of the leaf was determined from the scale reading and the curve. When the central disk is disconnected from the guard ring the quantity of electricity, Q, on the condenser and the collecting system with the electroscope remains constant. If the capacity of the electroscope is represented by K, the capacity of the condenser in the initial position by C_1, the capacity in the final position C_2, the initial distance between the plates by d_1, the final distance between the plates by d_2, and the radius of the central disk by r, then:

$$Q = V_1(C_1 + K) = V_2(C_2 + K)$$

$$V_1(C_1 + K) = V_2(C_2 + K)$$

$$K = (V_2C_2 - V_1C_1) \div (V_1 - V_2)$$

$$= \left(\frac{AV_2}{4\pi d_2} - \frac{AV_1}{4\pi d_1}\right) \div (V_1 - V_2)$$

$$= \frac{r^2}{4}\left(\frac{V_2}{d_2} - \frac{V_1}{d_1}\right) \div (V_1 - V_2)$$

The leaf could be brought back to its initial position by bringing the movable disk back to its initial position, showing that no appreciable leak had occurred during the process of measuring. The capacity was found to be 23.24 cm. for air and 27.50 cm. for carbon dioxide at 255 lbs. pressure.

The capacity was also determined by the heterodyne method. The condenser used was of the precision type made by the General Radio Company. The values for carbon dioxide were 27.1 for 255 and 26.2 cm. for 15 lbs. per square inch, respectively. The reason that these values are lower is perhaps due to the fact that the capacity of the wire connecting the condenser with the electroscope is eliminated by the heterodyne method.

In order to obtain the leak over the insulation and the leak caused by the ionization in the electroscope, outside of the ionization chamber, the chamber was exhausted to a few mm. of pressure and the discharge obtained. This was repeated at various temperatures up to 200° C. without any noticeable difference in the rate of discharge. Values obtained for the quantity of electricity lost by this leak, expressed as an equivalent ionization, varied from 1.05 to 0.98 ions per c. c. per second. Since this variation is within the experimental error, it was concluded that the discharge over the insulation was not affected by the temperature of the ionization chamber. This test also shed some light on the behavior of the walls of the vessel at high temperatures. Above 260° C., however, a decided increase in ionization was noticed.

The air used in the ionization chamber was compressed into a large tank by the liquid-air machine after it had passed through the drying and purifying process. It was further dried and cleaned by passing it to the ionization chamber through a 1½-inch pipe 3 ft. long into which had been placed a tray of phosphorus pentoxide and then through a pipe filled with glass wool. A tray of phosphorus pentoxide in the cooling jacket was expected to absorb any moisture left in after the first two processes of drying.

The pressure in the ionization chamber was read by means of an 8-inch Schaeffer and Budenberg test gauge ranging from 0 to 600 lbs. per square inch. The vessel was filled with air to 255 lbs., a cap screwed on the valve and sealed. The same air was kept in the chamber for thirty days without any noticeable change in pressure. After the ionization chamber had stood for a number of days so as to allow for the decay of any emanation that might have been in the air the observations were begun. It was at first thought that it would not

be possible to hold the pressure absolutely and for that reason the observations were begun at room temperature, carried to the maximum temperature and brought back to room temperature again. The mean should then be nearly the correct value, even if a small leak had occurred. It was soon found, however, that this was not necessary as no variation in pressure was detected. The method later adopted was to take a number of readings for one temperature and then go to the next. In this way more consistent readings could be obtained as the temperature of the chamber became more uniform by holding the furnace at the same temperature for two or three days. The greatest difficulty experienced was due to convection currents in the electroscope. The plate into which the amber was fitted had to be kept at constant temperature during an entire run. This was done by adjusting the height of the overflow can. The electroscope was wrapped with heavy layers of cotton in order to keep it at constant temperature. Any error caused by convection currents was corrected by checking the voltage for the position of the leaf for each observation.

The quantity of electricity, Q, collected on the electrode is expressed by the relationship:

$$Q = C(E_1 - E_2) = n\,e\,t\,V,$$
$$n = C(E_1 - E_2) \div e\,t\,V,$$

where n is the number of ions formed per c. c. per sec., C the capacity in cm., $(E_1—E_2)$ the change in the potential of the electrode in E. S. U., e the charge of the electron in E. S. U., t the time in seconds, and V the volume of the ionization chamber in c. c.

An electrode of Chromel wire, 0.5 mm. in diameter, was used. The wire was kept straight by a cylindrical brass weight attached to the lower end. Chromel wire was used on account of its low thermal conductivity. Three complete runs were made with this electrode when the ionization chamber was filled with air to 255 lbs. per sq. in. at 30° C. The results are shown in figure 6.

The low temperatures were obtained by passing liquid carbon dioxide into the tank surrounding the ionization chamber.

The Chromel electrode was replaced by one of a brass rod 3 mm. in diameter, supported by a short piece of Chromel wire. The results agree with those for the Chromel electrode within experimental error.

In order to check the ionization values with results obtained by other observers, a pressure ionization test was made. Tests were

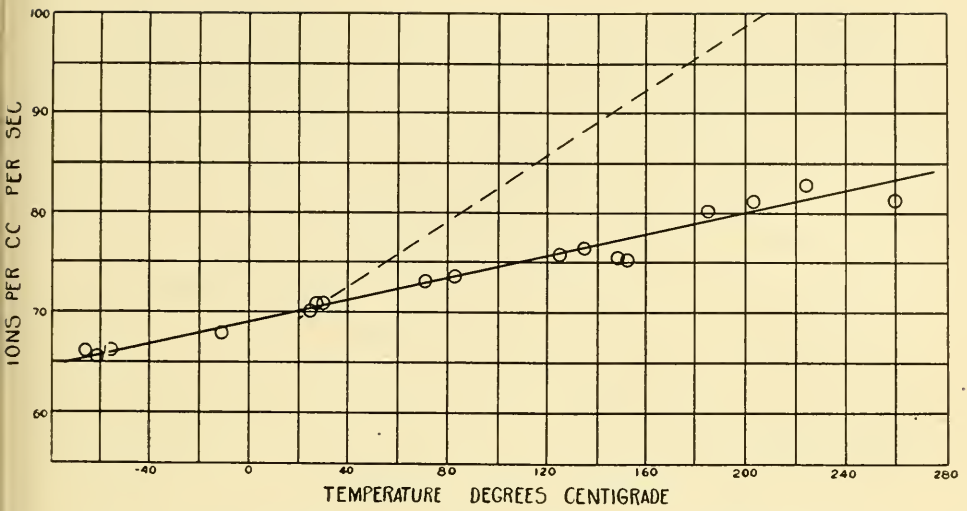

FIG. 6. Air curve showing relation between ionization and temperature, gas density remaining constant.

made with the Chromel electrode as well as with the brass electrode in air. The values are shown in figure 7.

The vessel was washed with carbon dioxide a number of times so as to drive most of the air out. It was then filled to 260 pounds with carbon dioxide. A pressure ionization curve was obtained, results of which are shown also in figure 7. The chamber was again filled with carbon dioxide and a temperature ionization test made. The results are shown in figure 8. It will be noted that one point is decidedly below the curve. The reason for this, no doubt, is that the carbon dioxide was in liquid form at that temperature and pressure. The pressure ionization curves obtained agree very well with those of Broxon and Steinke.

To make certain that the potentials used were high enough to insure saturation potentials various voltages were used. No increase in ionization was noted between 195 and 260 volts.

The observations show that for both air and carbon dioxide the ionization increases with temperature. For the sake of comparison, the trend of Patterson's[22] data for air, reduced to comparable pressures by use of the curve shown in figure 7, is indicated by the broken line in figure 6. The actual ionizations represented by Patterson's reduced data are three times those indicated on the ionization scale to which the present results are plotted. Thus the present

22. Patterson: Phil. Mag. 6, 231 (1903).

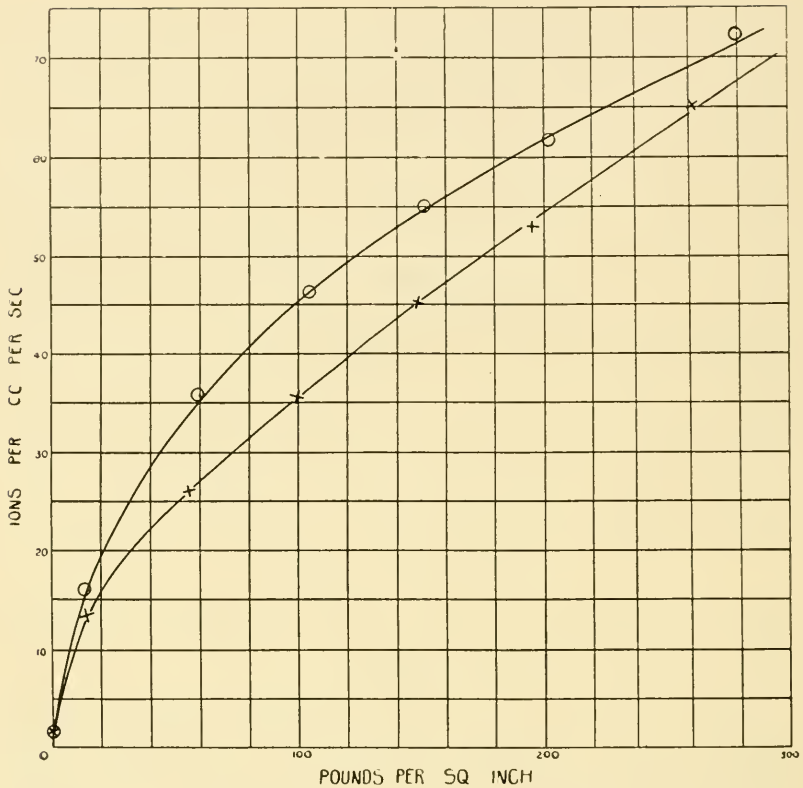

FIG. 7. Curves showing variation of ionization with pressure. Data for air represented by crosses. Data for carbon dioxide represented by circles.

observations yield ionization much lower than those of Patterson; also they show a distinctly less rapid increase with temperature.

One might think that the increase in ionization with temperature could be attributed to increased thermal agitation, but on considering that Steinke has reduced the residual ionization to 0.2 ion per c. c. per second, this source becomes less promising. By substituting in the equation for emission of electrons from hot bodies—

$$N = A T^{\frac{1}{2}} E^{-\frac{b}{T}}$$

for the range of temperature covered, one obtains values which are entirely negligible. Furthermore, the equation demands a more rapidly rising curve than that obtained. It does not seem probable that a penetrating radiation would cause a secondary radiation to

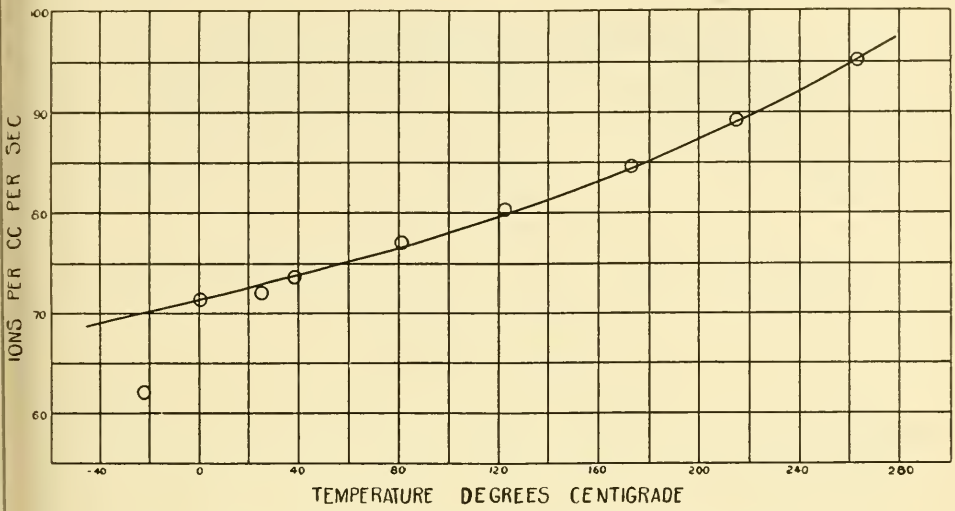

FIG. 8. Carbon dioxide. Curve showing relation between ionization and temperature, gas density remaining constant.

be given out by the walls dependent on the temperature. The increased ionization may be due to dissociation or to chemical action between the walls and the gas contained in the vessel. In carbon dioxide it is evident that chemical action had taken place between the electrode and the carbon dioxide, as the electrode was coated with a layer of copper oxide. If chemical action is the cause of the increased ionization, an inert gas like nitrogen should yield a different curve.

In conclusion the writer wishes to express his appreciation to the staff of the Physics Department for their kind interest, especially to Professor Kester for his aid and encouragement and to Professor Kent for many helpful suggestions. The writer is glad to acknowledge his indebtedness to Harry Snell, mechanician, for his assistance in solving many difficulties in the building of apparatus.

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Postnatal Growth Changes in the Single Comb White Leghorn Chicken.

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THE weights of some of the larger systems and organs of the chicken have been combined graphically in this paper to show the changes in the proportions of the chicken between hatching and maturity. The scale used in the figure will not permit the representation of some of the smaller organs, although some of these may be very important in the growth of the body. These data are taken from earlier papers on the postnatal growth of 94 single comb white Leghorn chickens from day of hatching to 300 days of age, and six older chickens from one to two years old. The details of the methods will not be repeated here since they are all recorded in the earlier papers together with some of the details not given here. (See bibliography.)

The weights of the systems were reduced to percentages of the net body weight, or the weight of the entire body minus the weight of the contents of the digestive tube. This was subtracted as it was felt that this was not a part of the organism. Figure 1 shows these percentage weights plotted against gross body weight in grams, as abscissæ.

MUSCULATURE. The muscles, represented as the lowest area in figure 1, constitute the largest percentage of any of the systems of the body throughout the entire postnatal growth period. They form 22 per cent of the body weight at hatching. They increase rapidly in early life and attain a maximum of 48 per cent in the adult. This percentage weight does not represent muscular tissue exclusively, for the weights of the blood vessels, nerves and fascia are included and an increasing amount of fat, which is by far the largest extraneous material in the older birds. The feathers are the only other system shown here with an increasing percentage weight

throughout the entire growth period. The weight of the musculature increases 153.3 times from hatching to maturity. This is a little more than twice the increase for the entire body weight of the chicken, which is but 70 times.

VISCERA. The viscera represented by the second area in the figure, form 21.4 per cent of the body weight, or the second largest part of the newly hatched chick. They decrease to 8.3 per cent in the adult, or they decrease from the second place in the newly hatched chick

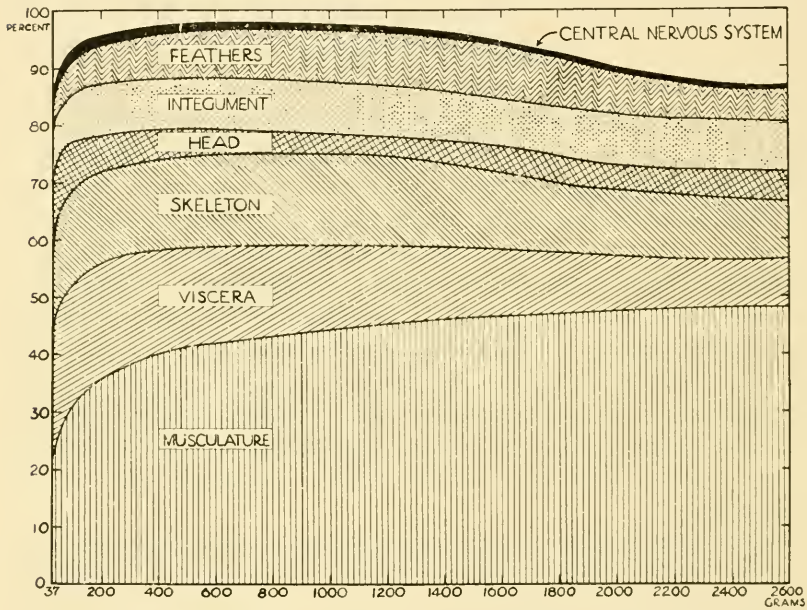

FIG. 1. The percentage weights of seven systems, plotted against body weight in grams. The percentages are shown as ordinates and the body weights as abscissæ. The unshaded area at the top represents the "remainder," as described in text.

to the fourth place in the adult. The viscera increase but 28.3 times during postnatal growth. The viscera, as they have been grouped for this study, include the digestive tube, liver, pancreas, kidneys, heart, spleen, thyroid, thymus, suprarenals and the hypophysis. All of these were weighed separately in the earlier papers, but they constitute too small a percentage of the body to be shown separately in this figure.

The largest part of the viscera is formed by the digestive tube, which forms 13.8 per cent of the body weight in the newly hatched chick and decreases to 4.1 per cent in the adult. Its maximum per-

centage of 14.1 per cent occurs at 100 grams of body weight. The liver decreases from 4.5 per cent of the body weight in the newly hatched chick to 2.1 per cent in the adult, and the similar percentages for the pancreas are 0.36 and 0.20 per cent. Each of these has a maximum at 100 grams of 4.80 and 0.62 per cent respectively. Mitchell *et al.* ('31) find the percentages of the digestive tract decreasing from 15.3 per cent to 9.72 per cent in the adult.

The maximum percentage of the viscera occurs at 100 grams of body weight and not at hatching, or 37 grams of body weight. This increase does not show well in this figure. The individual viscera showing a maximum percentage later than time of hatching are: intestines, liver and pancreas at 100 grams of body weight; kidneys at 300 grams, and the thymus at 1,100 grams of body weight. The thyroid decreases at first and then rises to a percentage greater than the hatching percentage in the postpuberal stage of growth. Some of this last increase may have been abnormal. The early increase in percentage weight of the intestines, liver and pancreas may be due to the demands suddenly placed on these organs, when, very shortly after hatching, the chick begins to eat food nearly as complex as that eaten by the adult. This means an increased task of elimination for the kidneys.

Byerly (*'32*) has suggested that the relatively smaller digestive tract in the older birds may be the explanation for the decreased rate of growth in the latter part of the postnatal period provided, of course, that it maintains a constant rate of efficiency. Another factor to be considered is that more of the energy derived from the food is used to maintain this increased mass and to move the larger body weight. In other words, it takes more food to keep this enlarged mass of living material going. In the younger chicks, with a smaller body weight, a much larger proportion of the output of the digestive tract is available for building the body and with increasing size this food material is diverted to maintenance. Without doubt there are other factors involved in this decreasing rate of postnatal growth. Whatever may be the cause of the change in growth rate, the viscera do constitute a decreasing percentage of the body weight as the chicken approaches maturity.

SKELETON. The ligamentous skeleton, shown in the third area from the bottom in the figure, is third in order of increasing percentage weight in the newly hatched chick, but it is second in relative weight in the adult chicken. It forms 14.8 per cent of the body weight at first, then rises to its maximum of 16.1 per cent at 500

grams of body weight, and then decreases to 10.2 per cent in the adult. These figures are for the males only, for in chickens with a body weight of 1,000 grams or more the female skeleton forms from 1 to 2.3 per cent less of the total body weight. The male skeleton increases 48.9 times and the female 38.7 times between hatching and maturity.

The ligamentous skeletons were cooked in a soap solution just long enough to free the skeleton from all attached bits of flesh and tendons and the moist cartilaginous skeleton was then weighed. These skeletons were later dried in an oven at 95° centigrade and the amount of free water was thus determined. This varied from 69 per cent of the weight of the cartilaginous skeleton of the newly hatched chick to about 35 per cent in an adult chicken. The six pairs of long bones in the wing and the leg were weighed in the dried condition and their increase in weight varied from 135 times for the female tibia to an increase of 396 times for the radius. The entire oven-dried skeleton increased 162.3 times for the females and 200 times for the males. Thus there is a good deal of variation in the growth of the parts of the skeleton itself as well as a marked sex difference in its growth.

HEAD. The head is shown as the fourth area in figure 1. The head of the chicken forms 12.6 per cent of the body weight at hatching. It then begins to decrease in relative weight to its minimum of 3.7 per cent at a body weight of from 1,300 to 1,400 grams, and then increases slowly to 5 per cent in the adult. These values used in plotting the area shown in figure 1 are for the males. The heads of the females show no appreciable sex difference in percentage weight until a body weight of 300 grams is attained. From this point on to maturity the heads of the females decrease to a minimum of 2.2 per cent in the adult. There is no secondary rise as in the case of the males. The heads of the females increase 13.3 times and the male heads increase 28.2 times during the postnatal growth period. The sex difference is due largely to the much heavier combs, wattles and ear lobes in the males. There is some difference in the head itself, for the heads of the males averaged about 9 per cent longer in all chickens above 110 days old. The percentage weights of the male and female heads reported by Mitchell *et al.* ('31) are slightly greater than these percentages except for the adult males.

INTEGUMENT. The skin, with as little of the subdermal fat as possible, but including the dermal muscles, the scaly skin of the legs and feet, the nails and horny covering of the beak, together form 8.9

per cent of the body weight throughout the entire postnatal growth period. The feathers had all been removed before the skin was taken from the body, so no feathers or quills of the feathers are included in the weight of the integument. This is the only part of the chicken which increases in weight at exactly the same rate as does the total body weight. Both increase 70.3 times from hatching to maturity. The percentage weight of the chicken integument is less than for the skins of many animals, but it does not include the weight of the feathers or the fur which is usually included in many mammal skins. Wiedersheim ('07) says that bird skins are usually thin.

The integument, shown as the fifth area in figure 1, is fifth in order of percentage weight in the newly hatched chick and third in order of increasing relative weight in the adult, surpassing in percentage weight the viscera and the head, both of which were heavier in the newly hatched chick.

FEATHERS. The feathers are sixth in order of relative weight in the newly hatched chick and fifth in the adult. They are shown as the sixth area in the figure. In the male they form 3.7 per cent of the body weight in the newly hatched chick, rise to their maximum percentage of 9.8 per cent at 1,100 grams of body weight and then decrease to 5.5 per cent in the adult. The percentages for the females are approximately the same up to about 1,300 grams of body weight and then their percentage weight drops more rapidly than that of the males and in the adult females the feathers form but about 4 per cent of the body weight. The female plumage increases 48.1 times during the postnatal growth and the male plumage 64.9 times. The maximum increases for the feathers are not found at the end of the period, but at 1,300 grams of body weight for the females, and 1,600 grams for the males, and these maximum increases are 61.3 for the females and 81.6 for the males. Mitchell ('31) finds a relatively heavier plumage in the females up to about 1,360 grams of body weight and thereafter the males have the heavier plumage. The resorption of the vascular mass, contained in the shaft or quill of the feathers until the completion of the growth of the feathers, is the probable cause of the decrease in weight of the plumage. The addition of the sex plumage in the male is probably the cause of the heavier male plumage.

CENTRAL NERVOUS SYSTEM. The solid black area at the top of figure 1 represents the nervous system. The brain and spinal cord together form 3.21 per cent of the weight of the newly hatched chick.

This percentage decreases rapidly at first and then more slowly to its minimum of 0.26 per cent at maturity. It is relatively the lightest of all the systems shown in figure 1, throughout the entire period. The eyeballs (not shown) and the nervous system each increase but 6.6 times during this growth period, showing that they are the two parts of the chicken growing the least during postnatal development. A study of the total growth of the various parts of the central nervous system shows that it does not grow as a unit, for the total increase of the brain weight from hatching to maturity is 4.2 times, while during the same period the spinal cord increases 18.9 times. The parts of the brain do not show as much variation for they range from a maximum increase of 4.7 times for the prosencephalon to a minimum increase of 3.7 times for the mesencephalon. The cerebellum increases 4.03 times and the medulla 4.5 times.

A comparison of the increase of the central nervous system of 6.6 times with an increase of 214 times for the pancreas shows that the total body increase of 70.3 times is indeed a composite figure, the result of the markedly different growth of the various organs and systems forming the total body weight. It is hoped that a better conception of the growth of the individual parts of the body will give us a better understanding of the growth of the entire body.

THE REMAINDER. The trachea and lungs are not included in this figure for in the chickens above 1,200 grams of body weight they varied so in weight that it seemed best not to try to determine an average weight. Mitchell ('31) does not find as much variability in the weights of the respiratory system of his specimens. This may be due, possibly, to a difference in the method of killing the birds. His birds were "killed by bleeding and debraining" and mine were all chloroformed, and then after the external measurements were made the head was removed and the body was hung up by the feet to permit the escape of the blood. It was first planned to weigh this blood, but it varied to such a degree that this plan was abandoned. The variability of the weight of the lungs seemed to be due to a varying amount of blood remaining in the lungs, due apparently to a variability in the time of clotting. Thompson and Carr ('23), in their studies, find a wide variation in the coagulation time of chicken blood.

Additional constituents of the "remainder" are the large vessels, nerves, mesenteries and fat which were all removed from the body without being weighed. These and the respiratory system, eyeballs and all of the reproductive system are not shown in figure 1. The

larger proportion of the body weight unaccounted for in the youngest chickens is due, in part, to the difficulty of accurately getting out and weighing the parts of these smaller chicks. In the older specimens the larger "remainder" is due to the increasing amount of the fat which was removed from under the skin, with the mesenteries, and from the sides of the body cavity and to the reproductive system. The "tare" or contents of the digestive tube is also a part of the remainder. Its weight was determined but found to vary considerably.

SUMMARY.

The seven systems presented here and which form the major part of the total weight of the chicken, form various proportions of the total body weight at the different stages of the postnatal growth.

The two systems, which form larger percentages of the adult body than that of the newly hatched chick, are the musculature and the feathers. The musculature increases to its maximum percentage in the adult. The plumage has its maximum percentage weight a little before half of the total body weight is attained and thereafter decreases somewhat, but forms a greater percentage of the body weight in the adult than in the young chick.

Only one system, the integument, grows at exactly the same rate as the entire body. It forms 8.9 per cent of the body weight throughout the entire postnatal period, and both increase 70.3 times.

Four systems are relatively heavier in the newly hatched chick, namely, the central nervous system, the head, the skeleton and the viscera. The central nervous system decreases in relative weight throughout the growth period. The viscera and the skeleton rise slightly to their maxima at 100 grams and 500 grams of body weight, respectively, and then decrease to a percentage less than in the young chick. The head decreases in percentage weight until near the end of the period, after which there is a slight terminal increase in its percentage weight.

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The Irritability of the Vagus Nerves of Dogs, as Shown by the Rheobase and Chronaxie, in Some Types of Tetany; and Their Relief by Calcium Salts.

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HISTORY.

THE symptoms, which develop following the removal of the parathyroids, indicate a modified irritability of the tissues. In 1916 Paton, Findley, Watson, and others (*19*), reported an increased excitability of the somatic motor nerves in parathyroid deficient individuals and animals. Normal animals receiving guanidine compounds showed a similar increase in the irritability of somatic motor nerves. This, with other evidence presented at the time, led them to conclude that the parathyroids regulated guanidine metabolism, and that deficient activity of the parathyroids resulted in an accumulation of guanidine-compounds in the body, which caused the increased irritability.

The parathyroids also have an important effect upon the irritability of tissues through their influence on calcium metabolism. The decrease in the blood calcium following the removal of the parathyroids was observed in 1909 by MacCallum and Voegtlin (*17*), and since then many have substantiated the decrease of blood calcium. J. Loeb in 1901 (*13*), MacCollum in 1905 (*16*), and Bouchaert and Colle in 1927 (*1*), showed that lowering the calcium content caused the irritability of tissues to be increased.

The symptoms do not appear when the blood calcium is maintained at its normal level. Parhon and Urechie in 1907 (*18*), followed by MacCallum and Voegtlin in 1909 (*17*), Luckhardt and Goldberg in 1923 (*15*), and Salvesan in 1923 (*20*), showed that parathyroidectomized dogs could be kept free from symptoms by fre-

quent administrations of soluble calcium salts, either intravenously or in larger quantities orally. Irradiated ergosterol and other substances rich in vitamin D have been used successfully in the prevention of the appearance of the symptoms in dogs following the removal of the parathyroids by Brougher in 1928 (*5*), Greenwald and Gross in 1929 (*11*), Demole and Christ in 1929 (*8*), and others.

Extracts of the parathyroid glands, prepared according to the method outlined by Collip in 1924 (*7*), have been very effective in relieving the symptoms resulting from the deficient activity of the parathyroids. The disappearance of the symptoms occurred as the blood calcium returned to the normal level.

The increased salivation and tachycardia following the removal of the parathyroids indicate an effect upon the autonomic nervous system or the effectors. Burns and Watson in 1918 (*4*) found that the vagus nerve to the heart showed a decreased excitability following intravenous injections of guanidine salts and after parathyroidectomy. The seat of action seemed to be on the preganglionic fibers first and then on the postganglionic fibers. In 1928 Stoland and Potter (*21*) reported that when methyl guanidine sulphate was given subcutaneously the vagus nerve to the heart became hyperexcitable initially, and as the effect of the guanidine became more pronounced the irritability would then be decreased as found by Burns and Watson (*4*).

In the above experiments on the irritability of tissues, only the intensity required to elicit a response was measured and taken as an index to the irritability. According to Keith Lucas (*14*), a stimulus must be of a sufficient time duration as well as of sufficient intensity to cause a response. Using electrical currents, Lucas (*14*) developed a method of demonstrating and measuring the time duration requirement.

Lapicque was instrumental in the development of a dependable and accurate method for the measuring of the time interval. The apparatus, as shown by Fulton (*10*), employs the use of condensers to measure the time durations. Lapicque has formulated the words rheobase and chronaxie to designate the strength and time duration of the stimulus necessary to elicit a response. His definition (*10*) of these terms is, "The rheobase is that intensity of a constant current closed instantaneously which will just excite if it is continued indefinitely; the chronaxie is that time of current flow required to result in an excitation when the intensity of the current is just twice that of the rheobase."

The modified irritability in conditions of tetany has been investigated by means of the chronaximeter method of Lapicque. Buchanan and Garven in 1926 (*3*) reported their observations upon the sciatic nerve in cats, which were in tetany following thyroparathyroidectomy and following injections of guanidine salts. The rheobase decreased and the chronaxie increased in the thyroparathyroidectomized animals, while in animals given guanidine the rheobase and the chronaxie were not noticeably affected. These results differed from those of Paton, Findley, and Watson (*19*), and led them to conclude the two types of tetany were not closely related.

In 1925 Bourguignon (*2*) in his experiments upon man found that in parathyroid deficient individuals and in cases of artificial tetany caused by hyperpnea, the onset of tetany was preceded by a lengthening of the chronaxies of the skeletal muscles and of their motor nerves. In one case of tetany from hyperpnea the increase of the chronaxie was preceded by a decrease. This individual would not breathe deep and rapid enough to induce an attack of tetany.

In 1929 A. and B. Chauchard and Czarnecki (*6*) found the irritability of the sympathetic nerves was lessened during the stage of tetany following the removal of the parathyroids.

These results, taking the chronaxie as an index of irritability, showed that a decreased irritability of tissues occurred following the removal of the parathyroids.

The effects of different types of tetany upon the irritability of the vagus nerve in terms of rheobase and chronaxie has been the subject of investigation by the authors.

Description of the Apparatus.

The apparatus used in these experiments (see diagram 1) is essentially similar to that described by Fulton (*10*) as used by Lapicque and others. For the earlier experiments the range was 1 to 270 volts in the condenser circuit; later, by means of a variable transformer with a rectifying tube connected to 110 volts A. C., this was increased, obtaining an intensity of 1 to 600 volts. In order to provide a steady, uniform current, a condenser pack of 6 mfds. capacity was placed on the D. C. side of the tube.

An electric tuning fork was used to supply stimuli at the rate of 82 per second. To the free end of the prong, and insulated from the balance of the fork, a copper contact was fastened. This was connected by a flexible wire to the variable condensers. The prong of

the fork in vibrating through its arc of 5 mm. would alternately charge and discharge the condensers by making and then breaking the electrical contact between them and the lead from the E. M. F. source at one end of its stroke and the lead to the animal at the other end of its stroke. These two leads were L-shaped; they would then bend somewhat at each contact, allowing sufficient time for the charging or the discharging of the condensers.

An electric interrupter of similar construction was used in a few experiments to supply stimuli at the rate of 11 per second.

The length of time that the stimuli were sent to the animal was two seconds, regulated by an adjustable speed, revolving electrical contact wheel, placed in the circuit between the condensers and the constant large external resistances.

DESCRIPTION OF METHOD.

Ether anesthesia was used during these experiments. The trachea was exposed, a cannula inserted into it, and connected to an ether bottle, where by means of valves the amount of ether administered could be regulated and then left constant. The left carotid artery was connected to a blood-pressure recording apparatus. The right vagus was then exposed and the electrodes placed upon it. These were nonpolarizing silver-chloride-coated silver electrodes of 0.3 mm. diameter, placed in a bakelite shield, which kept their contact with the nerve constant and always at a right angle. The distance separating the anode and the cathode was always 22 mm., with the latter nearer to the heart. As a precaution against polarization the current was reversed after each series of stimulations, thereby recoating the electrodes with silver chloride.

The irritability of the vagus was determined, taking as an index the fall of the blood pressure. The vagus was blocked centrally by pressure, only during the time that determinations were being made. In the last few animals it was found that a sufficient block was established at the anode by anodal electrotonus, so the use of pressure was discontinued. The quantities injected into the animals have been given in mgms. per kilogram of body weight.

RESULTS.

Ether anesthesia, according to Buchanan and Garven (*3*), exerts a marked effect on the rheobase and chronaxie of skeletal motor nerves. The method used minimized and kept constant the influence of the anesthesia as shown in the results given below.

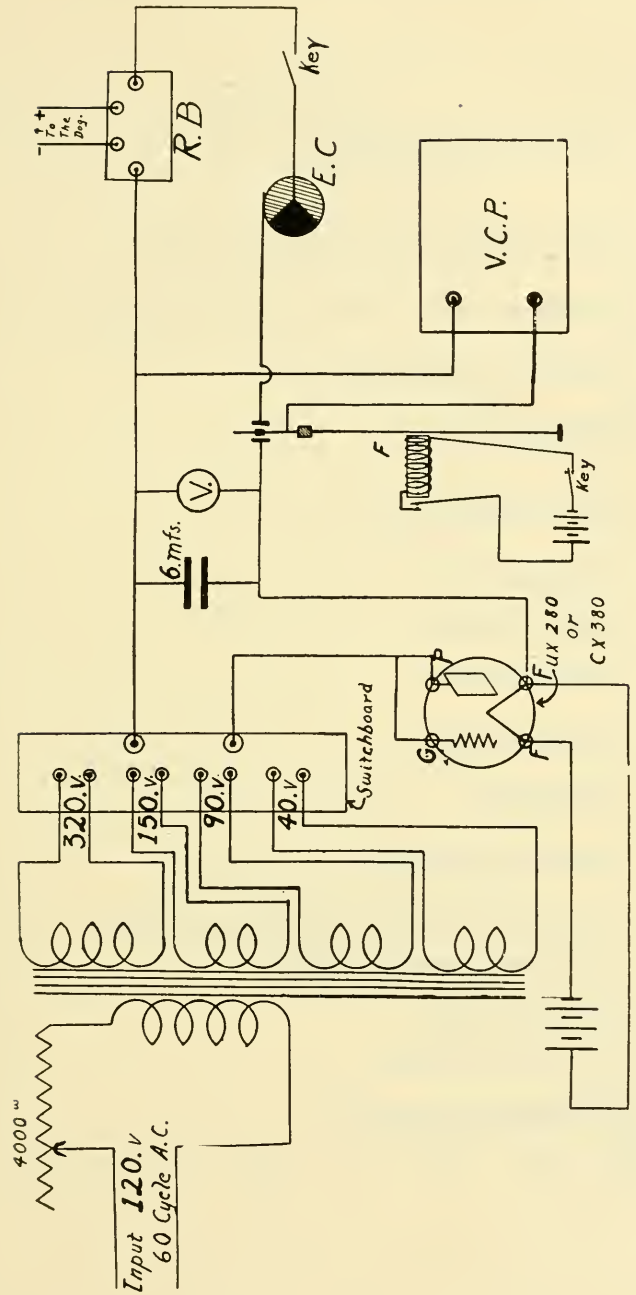

DIAGRAM I. Diagram of the circuit of the apparatus: *F*, Vibrating fork. *R.B.*, Resistance box (Lapicque. *V. C. P.*, Variable condenser pack. *E.C.*, Electrical contact clock.

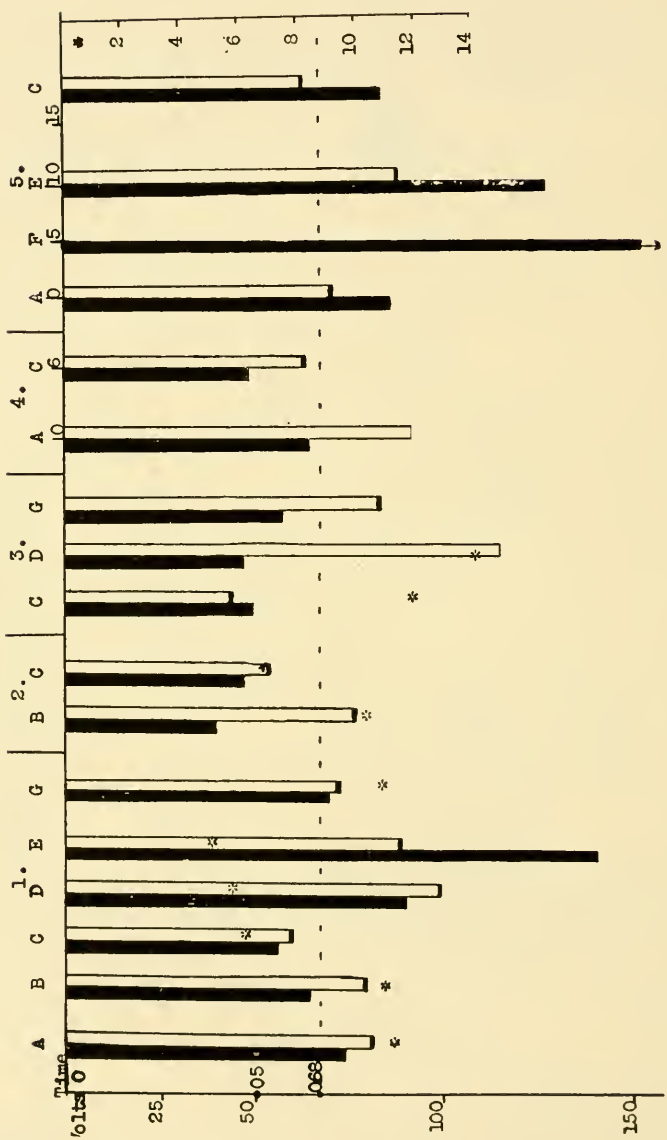

FIG. 1. The influence of parathyroidectomy and methyl guanidine sulphate on the irritability of the vagus nerve.

CODE OF FIGURE 1.

Groups.

1.....A. Twenty-five normal adult dogs.

1. Seventeen thyroparathyroidectomized adult dogs.
   - B. Two dogs showing the immediate effect.
   - C. Seven dogs in the stage of muscle tremors.
   - D. Two dogs in the stage of tetany convulsions.
   - E. Two dogs in the stage six hours following a convulsion.
   - G. Four dogs in which convulsions did not occur.

2. Three dogs injected intravenously with 6. to 170. mgms. per K. of sodium oxalate for 2 to 3 days.
   - B. One dog with the effect of a small quantity.
   - C. Two dogs in the stage of muscle tremors.

3. Eight adult dogs injected subcutaneously with 50. to 800. mgms. per K. of methyl guanidine sulphate during 1 to 4 days.
   - C. Three dogs in the stage of muscle tremors.
   - D. Five dogs in the stage of tetany convulsions.
   - G. One dog in which convulsions did not occur.

4. Five adult dogs injected intravenously with 6. to 15 mgms. per K. of M. G. S. during anesthesia.
   - A. Five normal adult dogs.
   - C. Five dogs in the stage of muscle tremors.

5. Five adult dogs injected intravenously with 50. to 150. mgms. per K. of M. G. S. during the anesthesia.
   - A. The normal values of these five dogs.
   - F. Following the acute administration of a large amount of methyl guanidine sulphate.
   - E. The same animals 5 minutes later.
   - C. The same animals after an additional 5 minutes.

Ordinates: Dark columns = rheobase in volts.
Light columns = chronaxie in sigma.
* = blood calcium in mgms. per cent.

Abscissa: Animals in groups.
Time in minutes.

The dogs used may be classed into five divisions: Group I, called control dogs, which were used to check the method and the effect of the ether anesthesia; group II, parathyroid deficient dogs; group III, dogs given methyl guanidine sulphate either subcutaneously or intravenously; group IV, dogs given sodium oxalate; and group V, dogs of the preceding four groups that were given calcium lactate or parathormone.

GROUP I—CONTROL DOGS.

This group is composed of forty-four dogs. From Table 1 it is apparent that light ether anesthesia does not affect the irritability of the vagus nerve to the heart. In the twenty-five adult dogs given light ether anesthesia the rheobase readings varied from 30 to 130

TABLE 1.—*Normal adult dogs.*

Number of dogs.	The condition of the animals.	Rheobase in volts.	Chronaxie in sigma.	B. P. fall in mm. of hg.
2	Decerebrated, 11 hours	90	0.074	10
2	Novocaine anesthesia	78	0.077	7
2	Chloroform anesthesia	54	0.087	6
1	Barbital anesthesia	80	0.068	10
4	Amytal anesthesia	70	0.08	10
25	Light ether anesthesia	74	0.082	10

volts with an average of 74 volts (see Table 2). The chronaxie values of 23 of the 25 normal adult dogs under ether anesthesia were between 0.068 and 0.09 sigma; and two were above this range, 0.11 and 0.12 sigma. Therefore, under light ether anesthesia the normal chronaxie value of the vagus nerve to the heart of dogs has been taken to lie between 0.068 and 0.09 sigma, when 82 stimuli are sent to the nerve per second for an interval of two seconds. In a few animals using 11 stimuli per second the normal value was between 0.05 and 0.074 sigma. In two dogs under local anesthesia (novocain), Table 1, the rheobase averaged 78 volts and the chronaxie 0.077 sigma. The readings of two decerebrated dogs, Table 1, averaged 90 volts and 0.074 sigma thirty hours after the withdrawal of the ether. The readings under ether anesthesia, mentioned above, do not differ greatly from those under local anesthesia or of those decerebrated.

The effect of various degrees of ether anesthesia upon the irritability of the vagi of dogs is shown by the data in Table 3. The depth of etherization was varied in nine of the twenty-five normal

control dogs. As the degree of etherization was increased, the average of the rheobases increased from 60 to 108, then to 240 volts, and the averages of the chronaxies were 0.083, 0.074, and 0.078 sigma. Upon allowing the animals to return to light ether anesthesia the rheobase became 80 volts and the chronaxie 0.08 sigma. Dog 53 was placed under barbital anesthesia and dog 10-M was given chloroform anesthesia. These animals were then given varying concentrations of

TABLE 2.—*Normal adult dogs under ether anesthesia.*

Dog No.	Rheobase in volts.	Chronaxie in sigma.
12	108	0.068
B-7	60	0.068
60.0	130	0.068
1	30	0.07
14-A	50	0.07
5	120	0.074
99	50	0.074
42	80	0.08
4	130	0.08
13	45	0.08
17	75	0.08
79	68	0.08
61	80	0.084
66	35	0.084
66-B	50	0.084
98	68	0.084
60	90	0.09
62	80	0.09
3	55	0.09
41	108	0.09
63	60	0.09
23-A	65	0.094
2-A	55	0.112
15-A	70	0.123
68	80	0.084
Average	74	0.082

TABLE 3.—*Effect of various depths of ether anesthesia.*

Dog No.	Number of dogs in group.	The condition of the animals.	Rheobase in volts.	Chronaxie in sigma.	B. P. fall in mm.
	25	Under light ether	74	0.082	10
	9	Under light ether	60	0.083	10
		Under medium ether	108	0.074	10
		Under deep ether	240	0.078	6
		Under light ether	80	0.08	10
53		Barbital anesthesia, 20 minutes	138	0.068	60
		After 50 minutes	140	0.068	55
		After 55 minutes, plus a small amount of ether	152	0.07	50
		After 70 minutes, plus usual amount of ether	185	0.074	60
		After 110 minutes, plus a large amount of ether	256	0.084	24
		After 170 minutes, ether was withdrawn	170	0.074	45
10-M		Chloroform anesthesia	45	0.09	6
		Plus a large amount of ether	260	0.09	6

TABLE 4.—*Effect of long continued ether anesthesia.*

Dog No.	Normal values.		After one hour.		After two hours.		After four hours.		After eight hours.	
	Rheobase in volts.	Chronaxie in sigma.	Rheobase in volts.	Chronaxie in sigma.	Rheobase in volts.	Chronaxie in sigma.	Rheobase in volts.	Chronaxie in sigma.	Rheobase in volts.	Chronaxie in sigma.
23A	60	0.094	58	0.07	55	0.07	30	0.066	.....	.....
77	75	0.08	65	0.074	68	0.07	52	0.07	70	0.08
46	55	0.079	62	0.068	63	0.074	40	0.07	65	0.08
42	110	0.074	80	0.078	100	0.074	80	0.07	80	0.084
Average	73	0.082	67	0.072	72	0.072	50	0.069	72	0.082

ether and the irritability of the vagus nerve was measured. From the data in Table 3 it is very apparent that the rheobase values were markedly increased and the chronaxies were not appreciably changed when the depth of the ether anesthesia was increased. Allowing the animal to become less deeply anesthetized, the rheobase again returned to the former value of light anesthesia.

The effect of the ether on the irritability of the vagus nerve was further investigated by taking readings at various intervals on four dogs over a period of eight hours of continuous ether anesthesia. The results are tabulated in Table 4, and averaged and charted in group 4 of figure 2. The chronaxies and rheobases decreased in these animals for the first four hours so that at this time the chronaxies were near the value of the lowest chronaxie of the twenty-five normal dogs. Eight hours after the starting of the ether anesthesia the chronaxies of the vagus nerves of these dogs were as high or higher than at any preceding time during the eight hours, yet they were not above the range of the normal control dogs.

TABLE 5.—*Normal pups.*

Number of dogs.	The condition of the animals.	Rheobase in volts.	Chronaxie in sigma.	B. P. fall in mm.
2	Amytal anesthesia	60	0.068	8
5	Light ether anesthesia	84	0.066	20
4 rat terriers from one litter	Light ether anesthesia	65	0.16	8

By comparing the data of Table 1 with that of Table 5, and groups 1 and 2 in figure 2, the vagus nerves of pups were shown to be more irritable than those in adult dogs. The rheobase readings of the vagus nerves of the pups were slightly above the average value of adult dogs; but the chronaxie values of four of the five pups under light ether anesthesia were below 0.07 sigma, and three of these were less than 0.068 sigma, which was the lowest normal value of the adult dogs. Four adult dogs were given amytal anesthesia. The irritability of the vagus nerves of these animals averaged rheobase 70 and chronaxie 0.08. (See Table 1.) Two pups were placed under amytal anesthesia. The irritability of their vagus nerves averaged rheobase 60 volts and chronaxie 0.068. Four rat terrier pups which were litter mates, had unusually high chronaxie values, averaging 0.16 sigma. The rheobase values of the vagus nerves of these animals averaged 65 volts. The high chronaxie values of the

FIG. 2. The effect of parathyroidectomy and methyl guanidine sulphate on etherized dogs: (1) Twenty-five normal adult dogs; (2) five normal pups; (3) six thyroparathyroidectomy adult dogs; (4) four etherized adult dogs; (5) five dogs injected subcutaneously with methyl guanidine sulphate, av. inj., 70 mgms. per K.

Ordinates: Rheobase in volts, and chronaxie in sigma.
Abscissa: Time in hours.

rat terrier pups may have been due to the fact that the mechanism of the vagus nerves to the heart was in a state of partial block, as a result of a hyperexcitability establishing a condition of heterochronism. Results given below, from other groups of dogs, indicate that a partial block may occur in this manner.

GROUP II—PARATHYROID DEFICIENT DOGS.

This group of dogs is composed of thyroparathyroidectomized dogs, and of dogs receiving blood from parathyroidectomized dogs.

The parathyroids were removed from thirty-two dogs. At various time intervals following the removal, these animals were sacrificed to determine the rheobase and the chronaxie of the vagus nerves that would effect a fall of the blood pressure of 10 mm. of mercury.

TABLE 6.—*Immediate effects following thyroparathyroidectomy.*

Dog No.	Normal values.		Stage of hyperirritability.			Stage of lessened irritability.		
	Rheobase in volts.	Chronaxie in sigma.	Time since T. P.	Rheobase in volts.	Chronaxie in sigma.	Time since T. P.	Rheobase in volts.	Chronaxie in sigma.
41	108	0.09	240	75	0.068	360	blocked	blocked
60	130	0.07	30	110	0.06	60	135	0.09
61	110	0.09	60	60	0.07	90	blocked	blocked
65	60	0.09	60	60	0.055	.....	.....	.....
			120	65	0.050	.....	.....	.....
66	30	0.084	30	26	0.05	90	22	0.12
Pups.								
62	130	0.068	30	110	0.06	60	130	0.1
64	83	0.063	.....	.....	.....	10	83	0.123

As shown by the data in Table 6, thirty minutes following the removal of the parathyroids under ether anesthesia, two of the five dogs, 60 and 66, had lower chronaxie readings than the lowest normal adult control dog. After an interval of one hour, four of them had chronaxie values below 0.068 sigma, the lowest normal chronaxie value. Before the removal of the parathyroids the chronaxie values of these animals ranged between 0.07 and 0.09, averaging 0.085 sigma. The rheobase values of the vagus nerves of these animals were also decreased. At this time the rheobase intensities required to effect a small and a large fall of the blood pressure were very close together, the difference being from 5 to 20 volts. Normally the difference was found to be from 30 to 50 volts.

These observations showed that the removal of the parathyroids from an etherized dog caused an increased excitability of the vagus

mechanism to the heart in less than an hour. Normal dogs, as reported in Table 4, showed that ether exerted a similar effect, yet it developed more slowly and was much less pronounced. The parathyroids retard and decrease this action of ether anesthesia upon the vagus nerves.

This change of irritability was not caused by any blood calcium change, for the results of five dogs in Table 13 showed no change in the blood calcium until one to three days following the removal of the parathyroids.

The initial period of hyperirritability was followed by a period of lessened excitability, which may have been the result of heterochronism. In dog 60, sixty minutes after the removal of the parathyroids, the rheobase of the vagus nerve had returned to its initial value and the chronaxie was above its original value, but within the range of the values of normal control dogs. In dog 66, ninety minutes after thyroparathyroidectomy, the rheobase was slightly below normal and the chronaxie was above the normal values. After ninety minutes in dog 61, and after six hours in dog 41, the stimulation of the vagus nerves with an intensity as high as 300 volts did not affect the blood pressure. A loss of irritability or a condition of block of the vagus mechanism to the heart had occurred.

The vagus nerves of control dogs under ether anesthesia (see Table 4) had lower chronaxie values in four hours, yet they were within the range of the normal control dogs. After eight hours of ether anesthesia, the chronaxie of the vagus nerves were approximately normal.

In figure 3, groups 5 and 7, and in figure 2, groups 3 and 4, the charts of the results of these animals show clearly the differences in the time of the appearance and the degree of the changes in the irritability of the vagus nerves of normal and parathyroidectomized dogs under ether anesthesia.

The data from two pups before and following the removal of the parathyroids is given in Table 6, and the times of the appearance of the modified irritability are chartered in figure 3, group 6. Their normal chronaxies were low, as were other pups; the stage of hyperirritability and of decreased irritability developed more rapidly than adult thyroparathyroidectomized dogs. In pup 64, the hyperirritability occurred and gave way to a decreased irritability in less than ten minutes. In pup 62 the chronaxie was 0.06 sigma thirty minutes after the removal of the parathyroids, and 0.1 sigma one hour after their removal.

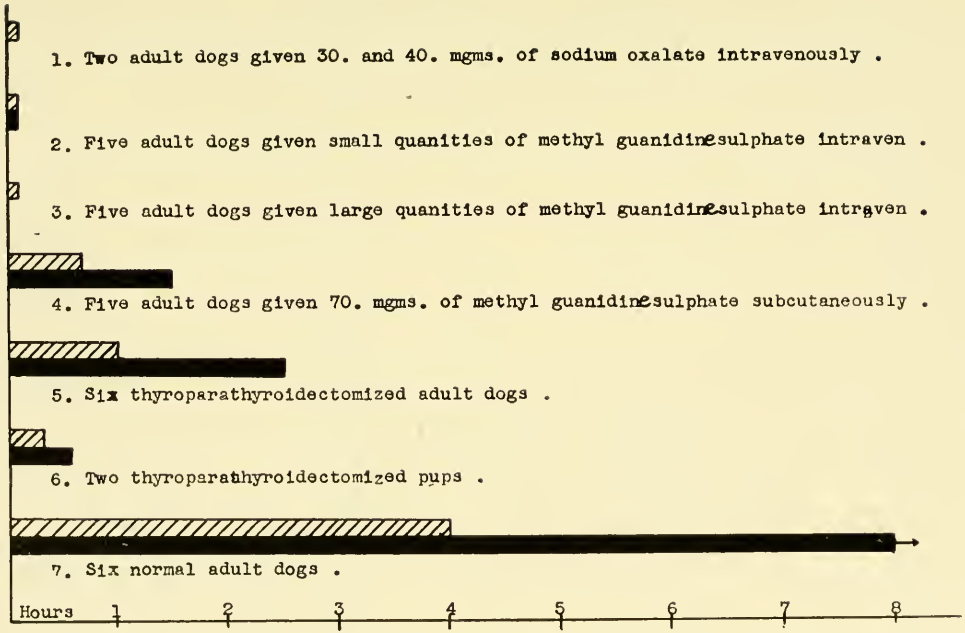

Figure 3. The effects of parathyroidectomy, sodium oxalate, and methyl guanidine sulphate on the irritability of the vagus nerves of etherized dogs .

Shaded columns , the time in which hyper-irritability developed .
Solid columns , the time in which decreased irritability developed .

Observations were made upon seventeen dogs following the removal of the parathyroids without the complicating action of long-continued ether anesthesia. (See Table 7.) Here the periods of ether anesthesia are comparable to the periods of the twenty-five normal dogs given in Table 2. The parathyroids were removed under a local anesthesia in two dogs, 58 and 74. Six hours later the animals

TABLE 7.—*Thyroparathyroidectomized dogs.*

Dog No.	Time since T. P.	The condition of the dogs.	Bl. Ca.	Rheobase in volts.	Chronaxie in sigma.
		Twenty-five normal dogs	11.2	74	0.082
58	7 hours	Bradycardia	11	60	0.06
74	5 hours	No symptoms	10.8	70	0.1
49	1 day	In muscle tremors		75	0.066
D-3	1 day	In muscle tremors		65	0.06
21	1 day	In muscle tremors		74	0.055
68	2 days	In muscle tremors	6.9	40	0.05
23	2 days	In muscle tremors		43	0.061
54-I	4 days	In muscle tremors		60	0.061
24	4 days	In muscle tremors		35	0.068
		Group C average		56	0.06
67		Tetany convulsions	5.7	95	0.1
27	5 days	Tetany convulsions*		35	0.1
		Group D average			0.1
75	3 days	6 hours following an attack	5.4	170	0.09
57-L	2 days	6 hours following an attack		200	0.12
		Group E average		185	0.105
56-K	3 months	Recovered, no active tetany		60	0.055
48-H	3 months	Recovered, no active tetany		80	0.084
22	13 days	Recovered, no active tetany		85	0.07
55-J	3 months, 10 days	Recovered, no active tetany		60	0.084
		Group G average		71	0.073

T. P.—Thyroparathyroidectomy.
* No ether was given this dog.

Interpretation of groups in all of the tables and figures:

A. Normal animals.
B. Dogs showing slight symptoms.
C. Dogs in the stage of slight tremors.
D. Dogs in the stage of tetany convulsions.
E. Dogs shortly following an attack of tetany convulsions.
F. Dogs with acute marked symptoms.
G. Dogs that recovered from the symptoms.

were etherized and their chronaxie values were 0.06 and 0.1 sigma. Shortly before anesthetization bradycardia had developed in dog 58, whose vagus nerve gave the chronaxie value of 0.06 sigma. In the remaining dogs of this group the parathyroids were removed under ether anesthesia, and the animals were allowed to recover from the effects of the ether. The animals were then again anesthetized, and

the irritability of the vagus nerve was measured when the dogs showed certain symptoms.

In the stage in which muscular tremors are present as a result of the removal of the parathyroids, the vagus nerves of all seven dogs were hyperirritable. As seen in Table 7, the chronaxies of the vagi of the animals in this stage were below 0.068 sigma, the lowest normal value, and the average of the rheobase readings was 30 per cent lower than the average of the values of the normal dogs. In figure 1, comparing groups A and C of group 1, the marked increase in the irritability of the vagus nerves is very evident. In this stage of parathyroid deficiency, the blood calcium content is decreased quite markedly, usually to 6 to 7 mgms. per cent, according to Esau and Stoland (*9*), and other workers.

Two dogs, 67 and 27, Table 7, in active convulsions at the time of etherization, showed a lessened irritability, the rheobase and chronaxie values both being higher than normal. In dog 27 the apparent low rheobase reading was due to the fact that during the anesthetizing of the animal a convulsive spasm interfered with respiration sufficiently long to cause the loss of cerebral action, but not of the lower brain centers, so that it was unnecessary to give ether to this animal, thereby eliminating the usual augmenting action of ether upon the rheobase. The blood calcium of dog 67 was 5.7 mgm. per cent.

Six hours following spasms of convulsions, the vagi of two dogs had chronaxie values very much similar to those of the dogs in convulsions. The rheobase readings were very noticeably increased, which might indicate a partial block of the vagus nerves due possibly to marked heterochronisms. The fall in blood pressure in these animals was delayed and persisted after the cessation of stimulation. The blood calcium of dog 75 was 5.4 mgm. per cent.

Four dogs recovered following the removal of the parathyroids without at any time showing symptoms more severe than mild tremors. After an elapse of thirteen days in one dog, a bull dog, three months in two dogs, and one hundred days in the fourth dog, the animals were sacrificed to determine the irritability of the vagus. The chronaxie of one dog was very much lower than the lowest value of the normal dogs. The chronaxie readings of the other three dogs and the rheobase values of all four dogs were in the normal range as shown in Table 7. The blood calcium was not determined on these dogs. In the work of Esau and Stoland (*9*), one of their dogs recovered from the removal of the parathyroids, and its blood cal-

cium had approximately returned to normal by three months. After three months the value was 10.7 mgm. per cent.

Dogs that survived the immediate symptoms of thyroparathyroidectomy usually had normal irritability of the vagus nerves in a few weeks following the removal of the glands.

Three dogs, in which the normal irritability of the vagus nerves had been measured, were injected with blood drawn from parathyroidectomized dogs showing various stages of symptoms. The results and conditions of the experiments are given in Table 8.

The chronaxie of dog 54-I, an animal in mild tremors (see Table 7) was 0.061 sigma. When 100 c. c. of its blood was injected into dog I, the chronaxie of this animal was decreased from 0.07 to 0.059 sigma, and the rheobase remained at its same value. The chronaxie

TABLE 8.—*Dogs receiving blood from thyroparathyroidectomized dogs.*

Normal values.		Injections from—		After 100 cc.		After 250 cc.	
Rheobase in volts.	Chronaxie in sigma.	Donor.	Group.	Rheobase in volts.	Chronaxie in sigma.	Rheobase in volts.	Chronaxie in sigma.
I 170.....	0.07	54 I	B	173	0.059	.....	.....
L 100.....	0.07	57 L	E	120	0.03	210	0.05
H 105.....	0.1	48 H	G	80	0.084	70	0.06

of the vagus of dog 57-L, an animal sacrificed six hours after a convulsive spasm (see Table 7), was 0.12 sigma, and the rheabase was 200 volts. When 100 c.c. of its blood was injected into dog L the chronaxie of the second animal was decreased from 0.07 to 0.03 sigma. A second injection of 150 cc. increased the rheobase to 210 volts and the chronaxie to 0.05 sigma. This would indicate that following parathyroidectomy the blood contained or was lacking in something that caused the vagus nerve to the heart to become increasingly irritable irrespective of whether the donor's vagus was hyper- or hypo-irritable.

The vagus of dog 48-H, whose parathyroids had been removed ninety days preceding, on recovering had a chronaxie value of 0.084 sigma. When 250 c.c. of its blood was injected into dog H, the chronaxie decreased from 0.1 sigma to the new value of 0.06 sigma, and the rheobase was decreased from 105 volts to 70 volts. The irritability of the vagus nerve of dog 48-H was normal, yet its blood, when injected into a normal dog, caused the vagus to become hyperirritable. Evidently the parathyroidectomized dog, 48-H, was able to maintain normal irritability of the vagus, in spite of the

change resulting from the removal of the parathyroids. During the interval of recovery, which was ninety days, the animal must have adapted itself to the changed environment.

These experiments upon transfusions have not been controlled, and therefore it is not safe to formulate any conclusions.

GROUP III—DOGS GIVEN METHYL GUANIDINE SULPHATE.

This group of animals consists of dogs given methyl guanidine sulphate in an acute manner either subcutaneously or intravenously, and of dogs injected for periods of one or more days. Fourteen

TABLE 9.—*Etherized dogs given methyl guanidine sulphate.*

Dog No.	Normal values of the vagus nerves.		Mgms. M. G. S. per kilo. Body weight.	The effect upon the vagus.		
	Rheobase.	Chronaxie.		Time in minutes.	Rheobase in volts.	Chronaxie in sigma.
3	55	0.09	12 intravenously	5	30	0.068
5	120	0.07	6 intravenously	5	70	0.08
2A	62	0.123	6 intravenously	5	65	0.06
8A	60	0.074	15 intravenously 30 intravenously	5 10	40 50	0.066 0.055
11A	28	0.112	6 intravenously	5	28	0.055
7	110	0.068	150 intravenously	5 20	over 170 109	..... 0.06
12	108	0.07	100 intravenously	5 20	over 170 110	..... 0.055
4	130	0.082	100 intravenously	5	over 270	.....
1	40	0.07	50 intravenously	15	37	0.08
14A	50	0.07	100 intravenously	10	130	0.09
23A	43	0.09	50 subcutaneously 210 intravenously	60 20	25 300	0.056 0.084
13	90	0.074	50 subcutaneously	35 80	52 80	0.06 0.115
17	75	0.08	50 subcutaneously	60 120	50 45	0.05 0.123
15A	70	0.123	100 subcutaneously	90	60	0.058

dogs under ether anesthesia were given methyl guanidine sulphate either subcutaneously or intravenously after first determining the irritability of the vagus nerves. The data are given in Table 9.

In dogs 3, 5, 2A, 8A, and 11A intravenous injections of small quantities (6 to 15 mgm.) of methyl guanidine sulphate caused a marked increase in the irritability of the vagus. The chronaxie and rheobase values of the vagus nerves of these dogs were normal pre-

ceding the injections. Five minutes after the injections four of the five animals showed a marked increase in the irritability of the vagus nerves. Their chronaxies were less than the lowest value of the twenty-five control dogs.

Larger intravenous injections (30 to 210 mgms.) resulted in a decreased irritability, as shown by dogs 7, 12, 4, 1, 14A, and 23A, in Table 9. The rheobase and chronaxie values of the vagus nerves were increased. After a short time, as the effect of the methyl guanidine sulphate became less pronounced or as a compensatory action appeared, the decreased irritability gave way to a condition of hyperexcitability, as shown by dogs 7 and 12.

Subcutaneous injections of 50 to 100 mgms. produced a marked increase in the irritability of the vagus nerves after thirty-five to ninety minutes, as was observed in dogs 23A, 13, 17, and 15A. The chronaxies decreased to values between 0.05 to 0.06 sigma in the four dogs. After one or two hours the vagus nerves of dogs 13 and 17 became less irritable. The chronaxies were 0.115 and 0.123 sigma. These changes of the irritability of the vagus resembled very closely those observed in parathyroidectomized dogs, as is shown by comparing group 3 with 5 in figure 2, and group 4 with 5 in figure 3.

The injections of the methyl guanidine sulphate were continued for longer periods of time in nine dogs. The data and results are given in Table 10. Two dogs, 65 and 88 (see Table 10), were injected with methyl guanidine sulphate subcutaneously. After two and five hours in the two cases, the animals developed bradycardia. The blood calcium values of these two animals were normal. These animals were anesthetized, and the irritability of the vagus nerves of both dogs was increased a great deal. The rheobase values were 38 and 70 volts, and the chronaxies were 0.04 and 0.055 sigma. The vagus nerve of dog 71, which had been injected subcutaneously with 400 mgms. of methyl guanidine sulphate during a period of two days, and which displayed tremors, increased salivation, and tachycardia at that time, was very excitable as was shown by its rheobase and chronaxie of 40 volts and 0.04 sigma.

Dogs 78, 76, and 69 were given injections of the guanidine salt for two or three days. The animals showed symptoms of difficult coordination and were depressed. The animals were anesthetized and the irritability of the right vagus nerve in each animal was measured. The rheobase values of the nerves were lower than normal, but the chronaxie values were higher, ranging from 0.09 to 0.135 sigma.

Dog 70 was injected until toxic symptoms of guanidine poisoning

TABLE 10.—*Dogs given methyl guanidine sulphate for various periods of time.*

Dog No.	Normal Bl. Ca.	Mgms. M. G. S. per K. injected subcutaneously.	The condition of the animals.	Group.	Blood Ca.	Rheobase in volts.	Chronaxie in sigma.
65	11.3	50	2 hours=bradycardia.				
			Etherized	B	11.8	38	0.04
88	11	90	5 hours=bradycardia		11.3		
			Etherized	B	12	70	0.055
71	11.2	100 on 1st day.					
		300 on 2d day	Tremors, salivation		12		
			Etherized	C	14	40	0.04
78	10.9	30 on 1st day			11		
		260 on 2d day	Tremors, difficult coördination		11.4		
			Etherized	D	11.9	38	0.123
76	10.6	50 for 2 days	Second day=bradycardia		10.6		
		250 on 3d day	Animal was very depressed		12		
			Etherized	D	14	42	0.135
60	11	280 during 2 days	Tremors, dyspnea		10.9		
		100 on 3d day	Depressed.				
			Etherized	D		60	0.09
85	10.6	100 on 1st day			10.9		
		500 during 3 days	Tremors		11.8		
		200 on 5th day	Convulsions		12		
			Marked convulsion, died		14		
70	11.4	400 during 4 days	Salivation, bradycardia.				
		50 on 5th day	Slight bradycardia		11		
		50 on 6th day	Inactive, but no symptoms		11.2		
			Etherized	G	11.7	58	0.084
9		20 for 50 days.					
		0 for 40 days	Appears normal.				
			Etherized	G		38	0.113

were apparent, then the amount of the injections was decreased until the animal showed no symptoms. The irritability of the vagus nerve was normal even though 100 mgms. of methyl guanidine sulphate had been injected during the twenty-four hours preceding the experiment.

Dog 9 was injected with 20 mgms. daily for fifty days. Forty days after the cessation of injections, the rheobase was low and the chronaxie was high, yet both values were within the range of the normal animals.

The blood calcium of these dogs showed just a slight increase. This might have been caused by the increased activity of the parathyroid glands, which resulted from the injections of guanidine salts, as was shown by Susman in 1926 (*22*).

GROUP IV—DOGS RECEIVING SODIUM OXALATE.

Eight dogs were given sodium oxalate. Of these three died in convulsions before the irritability of the vagus nerves could be determined. The observations from the remaining five are given in Table 11.

During two days dog 101 was injected with 6 mgms. of sodium oxalate. The blood calcium was not lowered, and the rheobase and chronaxie of the vagus were normal. The quantity of sodium oxalate given to this animal was too small to affect either the blood calcium or the irritability of the vagus nerve.

TABLE 11.—*Dogs given sodium oxalate intravenously.*

Dog No.	Normal Bl. Ca.	The condition of the animals—Mgms. injected.	Blood Ca. 1 d.	Blood Ca. 2 d.	After ether.*	Rheobase in volts.	Chronaxie in sigma.
101	10.3	6 Na. Ox., during 40 hours	10.6	10.2	12.5	40	0.078
		33 Ca. Lact., intravenously			15.2	83	0.115
						95	0.07
104	10.8	170 Na. Ox. during 3 days	9.3				
		Dog was sick—vomited		6.7	7.3	40	0.055
		Calcium Lact., intravenously			11	80	0.074
102	10.8	120 Na. Ox. with meals	9.2				
		100 Na. Ox. Injection, intravenously		8			
		Salivation, convulsion			5.7	55	0.055
81	12.6	Pup				68	0.074
		30 Na. Ox			8.3	80	0.115
		100 Ca. Lactate			16.5	50	0.06
		80 Ca. Lactate			21	56	0.074
99						50	0.074
		40 Na. Ox				40	0.09
		Thirty minutes later				92	0.061

* This column of blood calciums was determined on the dogs after the animals were anesthetized.

Two dogs were given sufficient sodium oxalate to produce toxic symptoms. Both showed hyperirritable vagus nerves. Dog 104, which had a normal blood calcium of 10.8 mgms. per cent, was injected with 170 mgms. of sodium oxalate for a period of three days. The blood calcium was decreased to 7.3 mgms. The rheobase was 40 volts, and the chronaxie was 0.555 sigma.

Dog 102, which had a normal blood calcium of 10.8 mgms. per cent, was given 90 mgms. of sodium oxalate orally and 120 mgms. intravenously during a period of three days. Three injections were made daily. The animal showed gradually increasing symptoms of oxalate poisoning by restlessness, copious saliva secretion, dyspnea, and muscle tremors. The animal's blood calcium was 5.7 mgms. per cent and the tremors were very marked. The rheobase of the vagus was 55 volts and the chronaxie was 0.055 sigma.

Under ether anesthesia the vagus nerve of a pup, dog 81, had a chronaxie of 0.074 sigma. The blood calcium of this animal was 12.6 mgms. per cent. Following the intravenous injection of 30 mgms. of sodium oxalate, the blood calcium decreased to 8.3 mgms. per cent and the chronaxie of the vagus nerve was 0.1156 sigma, which was an increase. Thirty minutes after an intravenous injection of 100 mgms. of calcium lactate the blood calcium increased to 16.5 mgms. per cent, and the chronaxie decreased to 0.06 sigma. A second injection of calcium lactate increased the blood calcium to 21 mgms. per cent, and the chronaxie to its normal value of 0.074 sigma. The effect of sodium oxalate on this animal resembled the effect of large acute intravenous injections of methyl guanidine sulphate, and the effect of parathyroidectomy on animals kept under anesthesia.

The normal values of the rheobase and chronaxie of the vagus nerve of dog 99 were 50 volts and 0.074 sigma. The injection of 40 grams of sodium oxalate decreased the rheobase to 40 volts, and increased the chronaxie to 0.09 sigma. Thirty minutes later the chronaxie was 0.061 sigma, and the rheobase was 92 volts. Compensatory mechanisms of the animal had partially eliminted the effect of the sodium oxalate.

GROUP V—DOGS RECEIVING CALCIUM LACTATE OR PARATHORMONE.

Twenty-two dogs of the preceding four groups were given calcium lactate in various quantities, and two dogs were given parathormone, five of the animals being normal. The results are given in Table 12.

Two pups, litter mates, were used to observe the effect of para-

thormone. The injection of parathormone increased the blood calcium of dog 94 from 11.5 to 16.5 mgms. per cent in twelve hours. The rheobase was 70 volts and the chronaxie was 0.07 sigma when the irritability of the vagus was measured. The blood calcium of the adult dog 91 was increased from 10.5 to 14.3 mgms. per cent sixteen hours following the administration of parathormone. The values found for the vagus nerve of this animal were: rheobase, 115 volts; chronaxie, 0.08 sigma. This chronaxie value corresponded with those of the normal control dogs. The elevation of the blood calcium in normal dogs by the administration of parathormone does not appreciably modify the chronaxies of the vagus nerves.

TABLE 12.—*Normal dogs receiving parathormone or calcium lactate.*

Dog No.	Normal Bl. Ca.	The condition of the animals.	Time since first injection.	Blood Ca.	Rheobase in volts.	Chronaxie in sigma.
93	.....	Normal pup (litter mate to 94, 95).....	.....	11.8	110	0.07
94	11.5	6 units parathormone.....	12 hours	16 5	70	0.07
		Twenty-five normals.....	.....	11.2	74	0.082
91	10.5	8 units parathormone.....	16 hours	14.3	115	0.08
80	11.3	Given calcium lactate.....	2 days	18.3	75	0.07
92	10	Given calcium lactate.....	2 days	18.7	60	0.09
		100 mgms., intravenously.....	30 min.	.....	110	0.074
93	.....	Normal.....	.....	.....	110	0.07
		200 mgms., intravenously.....	30 min.	.....	70	0.084

Dogs 80 and 92 were given calcium lactate over a period of two days until their blood calcium levels were 18.5 mgms. per cent. The vagus nerves of the animals displayed normal irritability. One of these animals was then injected intravenously with 100 mgms. of calcium lactate per kilogram. After thirty minutes the rheobase increased from 60 to 110 volts and the chronaxie decreased from 0.09 to 0.074 sigma. The chronaxie of the vagus nerve of dog 93 was 0.07 sigma and the rheobase was 110 volts. Thirty minutes after the intravenous injection of 200 mgms. of calcium lactate the rheobase of the vagus nerve decreased to 70 volts and the chronaxie increased to 0.084 sigma. This was opposite to the effect observed on dog 92. These animals showed that increasing the blood calcium above normal did not appreciably affect the irritability of the vagus nerve.

Two dogs that had been given sodium oxalate were injected with calcium lactate. The data and results are given in Table 11. The

blood calcium of dog 104 was increased from 7.3 to 11 mgms. per cent by the injection of calcium lactate. The rheobase of the vagus nerve was increased from 40 to 80 volts and the chronaxie was increased from 0.055 to 0.074 sigma. The calcium lactate caused the vagus to return to normal irritability. A pup, dog 81, which had been given 30 mgms. of sodium oxalate, was injected with 100 mgms. of calcium lactate intravenously. Thirty minutes after the injection the blood calcium was 16.5 mgms. per cent and the irritability of the vagus nerve was increased. The rheobase of the nerve decreased from 80 to 50 volts and the chronaxie decreased from 0.115 to 0.06 sigma. A second injection of 80 mgms. of calcium lactate raised the blood calcium to 21 mgms. per cent and caused the irritability of the vagus to become normal. The rheobase was 56 volts and the chronaxie was 0.074 sigma. The first injection of calcium lactate reduced the severity of the effect of the sodium oxalate, and the vagus showed the initial hyperirritability of oxalate poisoning. The second injection counteracted the effect of the oxalate. Acute oxalate poisoning is relieved by calcium lactate.

Nine thyroparathyroidectomized dogs were given calcium lactate. The data and results from these animals are given in Table 13. Of these dogs, seven were given calcium therapy after their blood calcium had decreased following the removal of the parathyroids. The blood calcium level of dogs 86 and 96 was kept approximately normal by administrations of calcium lactate. The animals did not display the usual symptoms following the removal of the parathyroids. The irritability of the vagus nerve was normal. The blood calcium of dog 95 was allowed to decrease slowly to 7.6 mgms. per cent on the sixth day after parathyroidectomy. The blood calcium was then maintained at this subnormal value until the eighth day, when the animal was sacrificed. The irritability of the vagus mechanism of the heart was normal. The severity of the symptoms has been found to be less when the blood calcium has decreased slowly as reported by Esau and Stoland in 1930 (*9*). The injection of sufficient sodium oxalate to reduce the blood calcium 25 per cent elevated the rheobase and lowered the chronaxie only slightly.

The blood calcium levels of four thyroparathyroidectomized dogs were allowed to decrease until the animals displayed marked tremors. Sufficient calcium lactate was then given to keep the blood calcium slightly above the level at which marked tremors appeared. The vagus nerves of dogs 83 and 105 were hyperirritable. These two animals had been given calcium lactate for two and three days

TABLE 13.—*Thyroparathyroidectomized dogs receiving calcium lactate.*

Dog No.	Normal Bl. Ca.	Blood calciums at intervals after the removal of parathyroids.											Values under ether.		
		1 hr.	3 hrs.	6 hrs.	½ day.	1 day.	2d.	3d.	4th.	5th.	6th.	7th.	8th.	Bl. Ca.	Rheobase.	Chronaxic.
86	12	.....	13.7	.....	.....	9*	7.9	9	9.7	9.2	.....	.....	.....	12.7 †14.5	40 48	0.086 0.084
96	13	.....	.....	.....	.....	.....	11.4	8.6	11.5	.....	.....	.....	.....	11.5	70	0.09
95	11.8	.....	.....	.....	.....	.....	8.5*	10	.....	.....	7.6	8	7.5	7.5 ‡5.5	60 120	0.09 0.08
84	10.5	11	11.4	10.8	11.6	10.6	7.9	5.4*	8	9.2	9	8	8.3	9.5 †12.5	50 70	0.067 0.04
105	12	.....	11.1	11.3	.....	6.8*	7.5	7.8	9	.....	.....	.....	.....	8.2	40	0.059
83	12.1	11.3	11	12.8	.....	11	8.5	6*	5.3	.....	.....	.....	.....	9.5 †15	70 65	0.04 0.03
106	11	11.9	10.8	9.4	.....	7.8	6.7*	6.6	7.8	.....	.....	7.4	.....	†10.7 †15 †23	over 300 160 115	..... 0.04 0.115
22		13 days after thyroparathyroidectomy												.....	80	0.07
		7 mgms. calcium lactate per K. intravenously												†	90	0.09
63		Normal												.....	60	0.09
		2 hours after thyroparathyroidectomy												.....	60	0.05
		20 mgms. calcium lactate per K. intravenously												†	40	0.09

* Calcium therapy started. † Calcium lactate injected 15 to 30 minutes previous to readings. ‡ Sodium oxalate injected intravenously.

respectively. The vagus nerve of dog 84 was only slightly hyperirritable. Calcium lactate had been given to this animal for five days. The vagus nerve of dog 106 showed a marked loss of irritability. This animal had been given calcium lactate for five days. The excitability of the vagus nerve in this animal may have been affected by the intravenous injection of calcium lactate that was given thirty minutes before the experiment. Supplying calcium lactate to these animals decreased the effect of parathyroidectomy upon the irritability of the vagus nerves.

The irritability of the vagus nerves of six thyroparathyroidectomized dogs was measured thirty minutes after the injection of calcium lactate. Two hours after the removal of the parathyroids, the chronaxie of the vagus nerve of dog 63 had decreased from 0.09 to 0.05 sigma. The injection of 20 mgms. of calcium lactate increased

TABLE 14.—*The effect of calcium lactate on dogs given methyl guanidine sulphate.*

Time—Mgms. injected per kilogm. body weight.	Time.	Mgms. Bl. Ca.	Rheobase in volts.	Chronaxie in sigma.
DOG 15A, hound, male, wt. 16 K., Group B	0:00	10.8	.....	.....
0:00 Etherized	0:50	12.2	70	0.123
0:55 100 M. G. S. subcutaneously	3:10	12	60	0.058
3:20 75 Ca. Lact. intravenously	3:50	22.2	70	0.09
4:10 15 M. G. S., intravenously	4:30	17.2	80	0.06
	6:00	16	100	0.06
6:10 250 Ca. Lact., intravenously	6:40	36	120	0.07
DOG 65, collie, female, wt. 9 K., Group B:				
0:00 50 M. G. S., subcutanecusly				
1:30 Etherized	2:00	11.8	38	0.04
2:20 25 Ca. Lact., intravenously	.....	.....	43	0.055
	2:30	.....	43	0.064
	2:40	14.2	50	0.084
3:00 50 Ca. Lact., intravenously	3:15	.....	33	0.085
	3:40	.....	40	0.084
DOG 71, male dog, wt. 14 K., Group C	0:00	11.2	.....	.....
2 days 410 M. G. S., subcutaneously.				
0:00 Etherized	0:10	14	40	0.04
0:15 57 Ca. Lact., intravenously	0:30	.....	40	0.05
0:35 57 Ca. Lact., intravenously	0:55	.....	40	0.06
*0:65 15 M. G. S., intravenously	1:25	.....	30	0.04
1:40 100 Ca. Lact., intravenously	1:55	.....	37	0.07
2:00 470 Ca. Lact., intravenously.				
4:00	4:10	.....	30	0.07
DOG 78, small spitz, female, wt. 5 K., Group D	0:00	10.9	.....	.....
2 days 290 M. G. S., subcutaneously.				
0:00 Etherized	0:10	11.9	38	0.123
0:15 30 Ca. Lact., intravencusly	0:25	.....	35	0.123
0:30 30 Ca. Lact., intravenously	0:35	.....	28	0.115
0:40 250 Ca. Lact., intravenously	1:20	.....	40	0.14
*1:30				
DOGS 76, spitz, male, wt. 11.3 K., Group D	.....	10.6	.....	.....
3 days 350 M. G. S., subcutaneously.				
0:00 Etherized	0:10	14	42	0.135
0:20 90 Ca. Lact., intravenously	0:30	.....	55	0.266
0:40 50 Ca. Lact., intravenously	0:50	.....	65	0.185
0:55 180 Ca. Lact., intravenously	1:00	.....	60	0.266
1:05 180 Ca. Lact., intravenously	1:10	.....	87	0.185
1:20 300 Ca. Lact., intravenously	1:40	.....	90	0.09

* Marked bradycardia occurred at these times.

the chronaxie to its original value of 0.09 sigma. During the thirteen days following the removal of the parathyroids, dog 22 had shown only slight tremors between the fourth and eighth days. On the thirteenth day, the irritability of the vagus was rheobase—80 volts, and chronaxie—0.07 sigma. After 7 mgms. of calcium lactate were injected these values became 90 volts and 0.09 sigma. The acute administration of calcium lactate to dog 86 had only a very slight effect on the irritability of the vagus nerve. Due to previous calcium therapy the irritability of the vagus nerve of this dog had become normal. Thirty minutes after the intravenous administration of sufficient calcium lactate to increase the blood calcium from 9.5 to 12.5 mgms. per cent, the rheobase of the vagus nerve of dog 84 was increased from 50 to 70 volts, and the chronaxie was diminished from 0.067 to 0.04 sigma. In this animal the calcium lactate seemed to have caused an excitable vagus to become hyperirritable. An effect similar but much less marked was observed in dog 83, while in dog 106 the effect was very marked. Increasing the blood calcium to 23 mgms. per cent in dog 106 removed the hyperirritable condition of the vagus. These dogs had been receiving calcium lactate several days following the removal of the parathyroids, as has been mentioned above.

The intravenous injection of calcium lactate given to dogs deficient in parathyroid activity caused the blood calcium to return to normal. The irritability of the vagus nerve did not become normal.

Calcium lactate was given to five dogs following the administration of guanidine (see Table 14). When the guanidine administration was acute, dogs 15A, 65, and 71, the injection of calcium lactate caused the vagus nerve to return to normal irritability. When the guanidine was administered over a period of several days the intravenous injection of calcium lactate affected the chronaxie, yet the irritability of the vagus was normal, as shown by dogs 76 and 78.

DISCUSSION OF RESULTS.

As given in Table 4 and figure 2, group 4, long-continued ether administration affected the irritability of the vagus nerves to the heart. First there was a gradual decrease of the chronaxie reaching a minimum in the average interval of four hours, then, after remaining hyperirritable for an interval between two and three hours, there appeared rather quickly a decreased irritability until the chronaxie readings were higher than normal.

The removal of the parathyroid glands resulted in the appearance of the hyperirritability in one hour instead of four hours, and the decreased excitability appeared in two and one-half hours instead of eight. This effect of the removal of the parathyroid is shown in figure 2, groups 3 and 4, and in figure 3, groups 5 and 7. In two pups the removal of the parathyroids caused the vagus to become hyperirritable in twenty minutes and the decreased excitability occurred after thirty-five minutes. This agrees with the fact that young individuals are more sensitive to toxins and ether anesthesia, and are more likely to suffer from lack of calcium and parathyropriva.

The subcutaneous administration of methyl guanidine sulphate to animals under ether anesthesia caused the vagus to become hyperirritable in forty minutes, reaching a maximal irritability in one and a half hours. In less than two hours the irritability of the vagus decreased below normal. Figure 2, group 5, and figure 3, group 4, show this effect of the methyl guanidine sulphate upon the irritability of the vagus nerve. When the guanidine salt is given intravenously the changes in the irritability of the vagus have occurred before the excitability of the nerve can be measured. (See groups 4 and 5, figure 1, and also Table 9.)

The period when the vagus nerve became less irritable following the initial hyperirritability may correspond to the crisis reported by Vincent and Thompson in 1928 (*23*). When this change is sudden the crisis is more apparent and acute. Pups usually had marked crises, and the changes in the irritability of the vagus nerves were quite rapid.

The guanidine salt and parathyroidectomy not only hastened the appearance of the hyperirritability of the vagus in etherized dogs, but caused a more marked hyperirritability. In four dogs the chronaxie decreased from 0.083 sigma to 0.068 sigma (average) as a result of ether anesthesia, while the chronaxie of six parathyroidectomized dogs decreased from 0.086 to 0.058 sigma (average), and five dogs given guanidine subcutaneously showed a decrease in their chronaxie of from 0.09 to 0.054 sigma (average). (See Fig. 2.)

Observations indicate the secondary decreased irritability may be a condition of a partial block caused by a heterochronism resulting from the hyperirritability. In some animals the fall of blood pressure lagged the vagus stimulation during the period of decreased irritability as if summation of the impulses was necessary. The injection of calcium eliminated this and caused the vagus to be hyper-

irritable. A large injection of calcium lactate would remove the hyperirritability.

Lapicque and Larrier (*12*) found that increasing the calcium increased the chronaxie of the tissues. In these experiments the injection of calcium lactate lengthened the chronaxie of the vagus nerve if it was hyperirritable. When the symptoms of parathyropriva or guanidine poisoning or oxalate poisoning were severe and had been produced in an acute manner, the vagus nerve had a large chronaxie. The injection of a small quantity of calcium lactate caused a large decrease in the chronaxie of the nerve. This marked increase in the excitability of the nerve may have been the result of the removal of an incomplete block due to the slight increase in the chronaxie caused by the calcium salt.

The blood calcium was not decreased by the injection of methyl guanidine sulphate. Rather, from the results in Table 10, it appears the level was slightly increased. This may be the result of the increased activity of the parathyroid glands. Susman, in 1926 (*22*), observed that small repeated injections of guanidine compounds caused a hypertrophy and hyperplasia of the parathyroid glands.

The results given in Table 8 of animals receiving blood from thyroparathyroidectomized dogs indicate the removal of these glands results in the appearance of some material in the blood to which a tolerance can be developed. Injection of only 100 to 200 c.c. of their blood caused the animals to show as pronounced changes in the irritability of the vagus nerves as were present in the animals with the parathyroids removed. Evidently the latter animals had developed a resistance or a tolerance to this substance; otherwise the effect of the injections of just small portions of these animals' blood would not have caused as large a change in the animals receiving the blood as had occurred in the donors. Dog 48H had recovered from the effects of the removal of the parathyroids, its vagus possessing normal irritability, yet the injection of 250 c.c. of its blood into dog H resulted in the chronaxie of the vagus nerve decreasing from 0.1 to 0.06 sigma. This would explain why the animals of Esau and Stoland (*9*) showed more pronounced symptoms when the blood calcium decreased quickly, and why Luckhardt and Goldberg (*15*) were able to slowly decrease the amount of calcium salts administered to thyroparathyroidectomized dogs.

In the animals in these experiments the chronaxie changes of the vagus to the heart were very similar to each other in the three types of tetany investigated. The apparent discrepancies of some of the

previous workers may be due to the lack of the use of the chronaxie method to measure the irritability of the tissues, to the different effects of various sizes of doses, to whether the administration was acute or slow, or to whether the animal was anesthetized for a period of time before the observations were taken.

The results of Buchanan and Garven, published in 1926 (*3*), lead them to the conclusion that there was no relationship between guanidine compounds and parathyroid tetany in their effect upon the electrical excitability of somatic nerves. They concluded that guanidine had no effect upon either the rheobase or the chronaxie. In their discussion they stated they found a slight decrease in the chronaxie following subcutaneous administrations, but that large injections did not affect the chronaxie. A study of their results in Tables 3 and 4, and figures 7 and 8 of their paper (*3*) shows that small doses of guanidine did affect the irritability of the somatic nerves in very much the same manner as it affected the vagus nerves. In small doses it diminished the chronaxie, and in larger doses the hyperirritability gave way to a state in which the values were fairly normal. From figure 3 of their paper the normal chronaxie of the nerve to the semitendinosus muscle was between 0.06 and 0.27 sigma. After the administration of guanidine salts the chronaxie values of this nerve in the same animal (see figure 7 of their paper) were between 0.03 and 0.14 sigma. Five of the ten readings that were taken were below the lowest normal reading of 0.06 sigma. Their Tables 3 and 4 are included in this paper as Table 15, together with the probable condition of their animals. Their results show that guanidine salts diminished the chronaxie of the somatic motor system. These chronaxie values following guanidine administration were approximately one-half of those in the normal state. According to Lapicque (*10*) a further decrease would establish sufficient heterchronism to cause a block of individual stimulus.

The results of Buchanan and Garven on the somatic nerves of parathyroidectomized cats do not agree with the results reported in this paper, yet this may be due to a difference in the animals or in the types of nerves measured. Their first observations were made twenty-four hours following the removal of the parathyroids and an initial hyperexcitability may have occurred during this interval, since they used ether as an anesthetic in removing the parathyroids. Their results with the parathyroidectomized animals agreed with the observations of Bourguignon (*2*) upon the somatic system in tetany conditions.

In Bourguignon's observations one individual, in which the tetany was being induced by hyperpnea, would not breathe deeply and rapidly enough to cause tetany. The chronaxie of the somatic nerve which was measured showed an initial decrease before the increase. There is a possibility that an initial decrease of the chronaxie might have appeared in all of the hyperpnea experiments if the development of the tetany had been delayed.

The somatic system and the autonomic system may be affected differently, yet further research may disclose both systems to be affected similarly.

TABLE 15.—*Interpretation of the results of Buchanan and Garven.*

Dates.	Interpreted condition of somatic nerves.	Rheobase in volts.	Chronaxie in sigma.	Injections gms. per kilogm.
	CAT 12—Deep flexors:			
	The normal average		0.24	
3-2-25	Preceding the injections	14	0.22	.05 di-m. g. cl.
3-3-25	Slightly increased irritability	18	0.15	.5 di-m. g. cl.
	Marked increase of irritability	15	0.11	
	Difficult conduction (blocked incompletely)	30	0.26	
	Returning hyperirritability	14	0.19	
3-4-25	Increased irritability	23	(av.) 0.14	
	CAT 8—Deep flexors:			
	The normal average		0.17	
2-5-25		30	0.13	.06 guan. cl.
2-6-25	Recovered	30	0.26	.1 guan. cl.
	Gradual increase of irritability	36	0.22	
2-7-25	Gradual increase of irritability	35	0.15	
2-9-25		31	0.07	.1 guan. cl.
	Decreased irritability developed	39	0.15	
2-10-25		40	0.26	.2 guan. cl.
		30	(av.) 0.28	
	Returning hyperirritability	30	0.15	

CONCLUSIONS.

A.—THE EFFECT OF ETHER UPON THE IRRITABILITY OF THE VAGUS NERVE.

1. Light ether anesthesia augmented the rheobase to some extent and had very little if any effect upon the chronaxie of the vagus nerve to the heart. To cause a marked fall in the blood pressure, using a frequency of 82 stimuli per second for two seconds, the readings of normal animals under light ether anesthesia were, rheobase 45 to 80 volts, and chronaxie 0.068 to 0.09 sigma.

2. When the depth of etherization was greater the rheobase was higher and the chronaxie changed very little.

3. Long-continued etherization caused the vagus nerve to the heart to have an increased excitability beginning usually in less than an hour and continuing until after the fourth hour. Later a period of approximately normal irritability developed. The values throughout both periods were within the normal range of the chronaxie values.

B.—THE EFFECT OF PARATHYROIDECTOMY UPON THE IRRITABILITY OF THE VAGUS NERVE.

1. The irritability of the vagus was initially increased following the removal of the parathyroids, the rheobase and the chronaxie were both decreased. Soon after the chronaxie reached a value in the vicinity of 0.04 to 0.06 sigma the vagus became less irritable, the rheobase increased, the chronaxie remained low for a short time but increased to the higher value of 0.09 to 0.123 sigma very suddenly. Calcium lactate given intravenously caused the vagus to be hyperirritable again, and in larger amounts restored the vagus to normal irritability.

2. When the dogs were etherized only during the time required to remove the parathyroids, the vagus nerve became hyperirritable in approximately six hours and continued to be hyperexcitable during the stage of tremors until the animals were in tetany convulsions. At this time the irritability of the vagus decreased.

3. When the dogs were kept under ether anesthesia following the removal of the parathyroids the increased irritability of the vagus was marked in 30 to 60 minutes and the chronaxie became less than 0.06 sigma. One to one and one-half hours after the removal of the parathyroids the chronaxies of the vagus nerves of all the animals except one in this group became larger suddenly. The value of the chronaxies varied between 0.09 and 0.123 sigma.

C.—THE EFFECT OF INJECTIONS OF METHYL GUANIDINE SULPHATE UPON THE IRRITABILITY OF THE VAGUS NERVE.

1. Dogs given 50 mgms. of methyl guanidine sulphate subcutaneously displayed bradycardia in two to five hours. When etherized the vagus was hyperirritable because the chronaxies were between 0.04 and 0.055 sigma. As the muscle tremors became fairly marked and the animals became somewhat depressed from the repeated subcutaneous injections of methyl guanidine sulphate, the chronaxies of the vagus nerves were between 0.09 and 0.135 sigma.

2. The vagus of animals which received from 10 to 15 mgms. of

methyl guanidine sulphate intravenously immediately became hyperirritable. Their chronaxies were between 0.055 and 0.066 sigma, while before the injections they were between 0.07 and 0.11 sigma. When 50 mgms. were given subcutaneously to etherized animals the chronaxies of the vagus nerves were below 0.06 sigma in thirty-five to ninety minutes, and the stage of decreased irritability appeared in eighty minutes to two hours, the chronaxies being between 0.1 and 0.123 sigma. The injection of calcium lactate resulted in the return of the irritability of the vagus to normal.

3. The injection of 50 to 150 mgms. of methyl guanidine sulphate intravenously caused the vagus nerves to be blocked for a short time. After five to twenty minutes, depending on the dosage injected, the vagus was hyperirritable. The chronaxies were less than 0.06 sigma.

D.—THE EFFECT OF THE ADMINISTRATION OF SODIUM OXALATE UPON THE IRRITABILITY OF THE VAGUS NERVES.

1. The chronaxies of the vagus nerves in dogs receiving small, frequently repeated, intravenous injections of sodium oxalate were 0.055 sigma when the animals displayed mild tremors.

2. The injection of 30 to 40 mgms. of sodium oxalate intravenously caused the chronaxies of the vagus nerves to be increased from the value of 0.074 sigma to values between 0.09 and 0.115 sigma. After thirty minutes the chronaxie of the vagus was 0.06 sigma. The vagus became hyperirritable rapidly if calcium lactate was injected, the chronaxie being 0.06 sigma. A second injection of calcium lactate restored the vagus to normal irritability.

E.—THE IRRITABILITY OF THE VAGUS NERVES OF PUPS.

1. The chronaxies of the vagus nerves of pups were lower than adult dogs. They were between 0.063 and 0.07 sigma.

2. The vagus nerves of pups were more susceptible to the effects of the removal of the parathyroids.

F.—THE RELATIONSHIP OF VARIOUS TYPES OF CONDITIONS THAT CAUSED TETANY IN THEIR EFFECT UPON THE IRRITABILITY OF THE VAGUS NERVES.

1. The removal of the parathyroids, the injection of methyl guanidine sulphate, and the administration of sodium oxalate caused an initial increase in the irritability of the vagus nerve to the heart, followed by a decreased irritability when the effect was pronounced or sudden.

2. This decreased irritability appeared to be the result of a sufficient heterochronism established as the hyperirritability of the parts of the vagus mechanism became more marked.

3. Long ether administration caused the vagus nerves of the animals to be more susceptible to methyl guanidine sulphate and to the removal of the parathyroids.

4. As the vagus became quite hyperirritable, the animals were in a state in which the crisis of Vincent and Thompson (*23*) might occur. The more sudden the rate of the development of the hyperirritability, the more apparent the crisis.

G.—THE EFFECT OF INCREASING THE BLOOD CALCIUM LEVEL.

1. The increasing of the blood calcium levels of normal dogs by the injections of calcium lactate or parathormone did not affect the irritability of the vagus nerves to the heart.

2. When the blood calcium was elevated and maintained at the normal level the irritability of the vagus nerves of thyroparathyroidectomized dogs, of dogs given methyl guanidine sulphate, and of dogs given sodium oxalate returned towards normal.

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Leptodactylus albilabris (Gunther): A Species of Toad New to the Fauna of the United States.

EDWARD H. TAYLOR.

AMONG the collections made in Texas during the summer of 1931 by J. S. Wright and myself is a small leptodactilid toad, which offers something of a problem in the way of identification. Through the kindness of Mrs. Helen T. Gaige, Museum of Zoölogy, Ann Arbor, the specimen was examined and dissected, and found to belong to the genus *Leptodactylus*. She also forwarded for comparison specimens of the species *L. albilabris* Günther from Vera Cruz, and St. Croix Island, which seem to approach this form in many characters.

From these two forms, which differ considerably from each other, I note that the Texas specimen differs in the absence of a distinct dorsolateral fold, the very much larger choanæ (nearly twice the area of those in the compared specimens), the presence of larger triangular bony prominences, on which the vomerine teeth occur, and their separation by a much greater distance (more than a half of their transverse length); the very narrow lateral fold is not continuous with the small supratympanic fold. There is a small forward extension of the snout to form a "nose." The dorsal coloration in life is ash gray to clay without black spots, while the compared forms are dark blackish brown with well-defined large dark spots.

From the specimen from St. Croix (the type locality of *Leptodactylus albilabris* Günther) I note that the tips of the digits are distinctly less widened, in fact not at all dilated; that the head is longer, more pointed; the eye relatively smaller; and that the ventral brown spotting is lacking.

From the Vera Cruz specimens it differs in having a flatter, more pointed head; a different coloration. It also differs in the points mentioned above. It agrees with both forms in the presence of a

well-defined cream-colored labial line, and the presence of a discoidal disk formed by a skin fold on the abdomen.

Cope* has described a species, *L. labialis*, which has small choanæ, and a paucity of dermal folds, and *L. gracilis*[1] with a projecting muzzle and having dermal folds.

Brocchi[2] has described *L. fragilis* with the vomerine teeth in arched series, with the tympanum nearly as large as the eye.

Remington Kellogg, who is reviewing the Amphibians of Mexico, proposes to place *labialis* Cope, *gracilis* Cope, and *fragilis* Brocchi all under the synonomy of *L. albilabris* Günther.

So for the present it seems that this Texas specimen must rest as *Lepidodactylus albilabris* Günther until a sufficient series of specimens are available to determine whether the separable characters, apparent in the specimen, are typical or due to individual variation.

The specimen was taken late at night hopping about on the table-like top of one of the row of hills just north of the Los Olmos bridge, near Rio Grande City, Tex. The earth was dry, and no rain had fallen for a period of forty-eight hours. The species probably shelters itself in the crevices of the rocky ledge which surrounds the top of the hill.

The following description will serve to identify this species:

The snout oval, the outline broken by a slight pointed projection of the "nose"; the head measures, length 11.5 mm. to angle of the jaw; the width at same point is 9.7 mm.; canthus rostralis rounded, the ridge continued downward in front of eye; between this ridge and the nostril the loreal region is distinctly concave; eye moderate, length of orbit 3.7 mm., the distance from the nostril 2.8 mm., and its distance from the tip of the snout 4.2 mm.; tympanum very distinct, rounded, 1.7 mm. long by 1.5 mm. high, separated from eye by half its greatest diameter; a slight supratympanic fold from eye, involving upper edge of the tympanum but bending down some distance behind the posterior edge of tympanum; labial fold distinct posteriorly, becomes very indistinct anteriorly and terminates below nostril; in lateral profile the snout extends beyond the mouth; the angle of mouth reaches directly below tympanum; the distance between orbits 2.4 mm.; of upper eyelid width 1.8 mm.

Skin on head smooth, showing microscopic corrugation; the dorso-lateral fold wanting, represented by a few low rounded or somewhat

* Cope: Proc. Am. Phil. Soc. XVII (1877), p. 90.

1. Cope: Proc. Amer. Phil. Soc. (1869), p. 162.
2. Brocchi: Bull. Soc. Philom. 1 (1877), p. 182.

elongate pustules; a sharply defined, very narrow lateral fold extends from above arm to groin; above this a few elongate or rounded pustules low and indistinct; below this fold the skin on chin, breast, abdomen and limbs smooth except for a strongly granular distinctly limited area on ventral femoral region; two prominent granules below anus; a transverse fold across the breast between insertion of arms more or less connected with a lateral abdominal fold, which curves across the posterior abdomen, forming a disk; a small diagonal fold running back from edge of disk to pubic region; limbs not especially long, the tibia 12.5 mm. is distinctly longer than the femur 10.1 mm.; from heel to tip of longest toe 19 mm.; an elongate sharply defined inner metatarsal tubercle, and a smaller rounded outer; subarticular tubercles strongly defined save under the last distal joint; heel tubercular with a distinct fold; rows of small tubercles below the metatarsals; tips of digits not dilated, the terminal phalanx (bone) pointed, somewhat clawlike; no webs present or only vestiges; two large palmar tubercles, an elongate inner at base of thumb, and a larger rounded basal tubercle with an anterior extension; first row of subarticular tubercles strongly defined; the first finger longer than second by the length of the last phalanx.

Color: Above rather lead gray with a few very irregularly scattered, slightly dark, grayish blotches; a dark vitta from snout through nostril to eye, continued behind to the tympanum; another irregular black line begins above tympanum and follows the supratympanic fold; below this a narrow, well-defined cream line, bordered below on lip by an irregular, less intense, dark line continued to angle of jaw; a few black spots on posterior part of lower jaw; arm with a few small dark spots, and a few also in axillary region; anterior side of femur with a dark horizontal line and small spots; upper and posterior surface of limb spotted; an indistinct cream horizontal line borders the granular edge of the under part of the femur, below which are a few small dark spots; under surface of chin through abdomen and limbs uniformly cream; a dark broad line from heel across foot. The measurements are, head and body, 25 mm.; foreleg, 13 mm.; hindleg, 40 mm.

The openings of the choanæ are well back from tip of snout—2.5 mm.—their entire outline plainly visible; vomerine teeth on two triangular raised patches, separated by slightly more than half their greatest width; they are between and almost wholly behind choanæ and border the raised eye sockets.

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The Toad *Bufo marinus* (Linnæus) in Texas.

EDWARD H. TAYLOR and JOHN SUAREZ WRIGHT.

THE writers, while collecting along the highway between Zapata and Arroyo Loma Blanca, in southern Texas, on the night of August 20, 1931, encountered a number of toads in a temporary pool, which on examination proved to be the widespread *Bufo marinus* (Linn), the largest known species of *Bufo*.

The water in which they were found was in an elongate pool approximately 100 feet long and in no place more than three feet wide, and not more than one foot deep at any place. Most of the specimens were found seated in the edge of the water and at the approach of a light they would disappear in the water only to reappear shortly on the opposite bank. At this place twenty-two specimens were captured, among them several large females. No pairs were found in copulation and no males were heard calling. No eggs were observed.

Later in the night camp was made at Arroyo Loma Blanca, and here the males were heard calling. Nine more specimens were found in the pools of the arroyo, apparently all of them males.

In both localities there were large numbers of *Rana pipiens* Schreber, but no other amphibians were found save a single specimen of *Bufo debilis* Girard and one specimen of *Gastrophryne texensis* (Girard).

An examination of the stomach contents showed that they had been feeding on large tenebrionid and carabid beetles, the bulk of the food being of the genera *Eleodes* and *Pasimachus*. Remains of other insects were in such state as to be unidentifiable in a cursory examination.

None of the specimens taken reach the size of Brazilian specimens (22 cm.) as reported by Miranda-Ribero.[1]

Description of species: No. 13101, Kansas University Museum, collected August 20, 1931, between Zapata and Arroyo Loma Blanca, southern Texas, by John Suarez Wright and Edward H. Taylor.

1. Gymnobatrachios (Anura) Brasileiros, Archivos do Museu Nacional do Rio de Janeiro, XXVII, 1926, p. 134.

Snout moderately long, somewhat rounded in profile; interorbital region strongly concave, gradually becoming shallower toward the snout; canthal ridges begin at a point above the nostrils and continue to anterior corner of eye, where they continue with the prominent supraorbital ridge, which continues in a circular course to the posterior corner of the eye, where it turns diagonally backward and continues to the parotoid; a postocular ridge is evident for a short distance anterior to the tympanum; a preorbital ridge is present and meets the supraorbital ridge at its junction with the canthal ridge; nostril about equidistant from the nearest edge of the lip and the anterior corner of the eye; the diameter of the eye is equal to its distance from the most anterior point of the snout; eyelids with a strongly defined free edge; tympanum oval, diagonally placed, separated from orbit by a distance equal to its shortest diameter; a strong, flattened, maxillary ridge, evident from a point under the anterior edge of the eye, continues back to the posterior edge of the jaw; loreal region somewhat concave; nostrils elongate, pierced diagonally; parotoids enormous, as long as the head, much longer than wide, diagonally placed, distinctly pitted; dorsal surface of body covered with rounded, flattened tubercles or pustules of varying sizes; a more or less regular paired series of pustules extending from the occiput to above anus; each of the pustules on the dorsal surface is surmounted by a spine which is so low as to be scarcely discernible save on the femur and tibia of the males, where they are distinct; to the touch the skin feels relatively smooth; the entire under surface of the body and limbs is granular in character, each granule with a slight spiny projection almost too low to be sensed by touch; eyelids strongly tubercular; an enlarged series of tubercles passes backwards from the posterior edge of the parotid gland.

Toes about half webbed, the fourth elongate with well-defined lateral flaps; inner metatarsal tubercle raised, oval, the anterior edge slightly free; outer metatarsal tubercle irregular in shape, high anteriorly, more flattened posteriorly; a sharp-edged skin-fold continues on the side of the foot behind the inner metatarsal tubercle, the inner margin of which extends forward as a small lobe; a small oval pollicary tubercle; prominent tubercles at the base of each finger, that of the first much the largest; entire surface of hands and feet covered with flattened tubercles of various sizes.

Color: Above, variegated brown with indefinite, lighter, irregularly placed blotches of light cream to dirty light-brown color; these spots distinctly lighter on the sides; ridges on the head a deep horn color; edge of lip, tips of tubercles, tips of toes deep black brown;

iris black with blue and gold flecks; belly and under side of limbs cream with the tip of each granule deep brown.

The only known toad in Texas with which the present species might be confused is *Bufo valliceps*, but the markings, the higher, sharper cranial ridges, the smaller parotoids, the higher, more pointed tubercles, and the smaller outer metatarsal tubercle of this species will readily distinguish it.

It will be seen that the above description differs in a few negligible points from other descriptions of this species. We do not find anything, however, to warrant a subspecific designation.

We are aware that this species has been artificially introduced into certain West Indian Islands; however, we do not believe that its presence in southern Texas must be accounted for in this way. It is probable that it ranges only a short distance north of the Rio Grande, but it will doubtless be found to range in suitable territory south of the river, connecting our territory with that now known to be occupied by the species in Mexico. It is an interesting addition to our known United States fauna.

The following table of measurements gives the variation that obtains in the series:

Table of Measurements of *Bufo marinus*.

K. U. Number.	Length.	Fore leg.	Hind leg.	Parotoid.		Diameter eye.	Diameter tympanum.
				Length.	Width.		
13101	168	84	184	47	31	18	11
13102	162	82	177	42	30	13	9
13103	147	78	174	38	28	12	8
13104	145	75	167	38	26	14	8
13105	136	69	170	38	21	13	7
13106	127	69	153	34	23	12	8
13107	126	70	147	35	24	12	7
13108	118	63	145	34	18	10	7
13109	114	64	153	36	18	8	7
13110	113	61	149	35	18	9	7
13111	108	63	130	28	30	11	7
13112	105	52	126	22	14	8	7
13113	104	50	128	24	15	7	6
13114	103	56	137	28	15	8.5	6
13115	99	51	114	22	11	7	6
13114	96	46	118	23	11	7	4.5
13115	94	54	117	22	12	7	6
13116	91	50	111	23	16	9	7
13117	89	47	117	22	12	7	6
13118	87	49	106	22	14	7	6
13119	83	45	107	22	10	6	4
13120	83	46	106	20	11	7	6
13121	78	44	97	20	12	6	6
13122	77	38	93	17	10	7.5	5.5
13123	77	39	104	18	13	7	6
13124	76	44	96	19	11	7	5.5
13125	76	38	98	18	10	6.5	4
13126	75	43	92	20	11	5.5	4.5
13127	70	39	93	18	10.5	7.5	5.5
13128	69	40	103	18	9	6	4
13129	66	36	87	16	11	5	4

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Eumeces inexpectatus: A New American Lizard of the Family Scincidæ.

EDWARD H. TAYLOR.

AMONG collections of *Eumeces fasciatus* from the southeastern part of the United States I have noted a form resembling *E. fasciatus* and *E. laticeps* in general type of coloration, yet differing so constantly in certain details of scalation, as well as in details of color markings, that I have no hesitancy in announcing it as a species related to but entirely distinct from either of these forms.

The species occupies territory that is likewise inhabited by the typical *Eumeces fasciatus* and *Eumeces laticeps** and for this reason, doubtless, has not been hitherto recognized by herpetologists as distinct from these species.

The present known distribution extends from Pinelas county, Florida, on the western coast, through northern Florida, northern Mississippi, and east to North and South Carolina. Like most of the known species of *Eumeces,* it varies in many of its characteristics, but apparently always may be distinguished from either *E. fasciatus* or *E. laticeps* in the same locality.

Eumeces inexpectatus sp. nov.

TYPE: No. 8232 Kansas University Museum: Collected Citrus Co., Florida, by Dr. Charles Burt, Mar. 7, 1930.

DIAGNOSIS: One of the *quinquelineatus* group showing characters somewhat intermediate between *Eumeces laticeps* and *Eumeces fasciatus* as to size, number of labials, temporal scales, scale rows and markings; usually one nuchal, one postnasal and two postmentals; upper labials seven or eight, the last largest, followed by an elongate well-differentiated postlabial which reaches the ear; median preanal scales rather small; 30-32 scale rows about middle of body, sub-

* A paper is in press giving reasons for the recognition of this species.

caudal scales not distinctly enlarged; lower secondary temporal does not reach ear.

DESCRIPTION OF TYPE: The portion of the rostral visible above a little less than half the bulk of the frontoparietal; internasal large, forming a relatively short median suture, touching postnasal and loreal laterally; frontonasal much broader than long, touching the anterior loreal laterally; the sutures with the internasals somewhat shorter than those with prefrontals; latter large, broadly in contact medially, forming subequal sutures with the first supraocular and first superciliary; frontal about a fourth longer than its distance from the end of the snout; distinctly wider anteriorly than posteriorly, the sides gradually sloping, in contact with three supraoculars; frontoparietals moderate in size, forming a suture half their length; parietals very broad, not inclosing the interparietal; a pair of large nuchals; nasal divided, the posterior part forming a narrow rim about nostril; a relatively large postnasal; two loreals, the anterior very little higher than the second, which is elongated; two presuboculars; 5-4 postsuboculars; primary temporal quadrangular, nearly square; upper secondary temporal elongate, widened but little posteriorly; lower secondary nearly triangular, the longest side next to the labial; two elongate tertiary temporals following behind the secondaries; nine superciliaries, the first and last largest; three small preoculars; two small postoculars; large opaque plates on lower eyelid separated from subocular by four rows of tubercles; median upper palpebral scales form sutures with the superciliaries; eight upper labials, first with posterior part much elevated above the succeeding four, which precede the subocular; seventh distinctly smaller than eighth, which is the largest; this followed by an elongate curved postlabial which enters ear, with two small scales in contact with it above; on left side the posterior is very small; three small free lobules on anterior border of ear; six lower labials; mental with much greater extent on lip than rostral; two postmentals; chinshields typical, the last followed by two scales, the outer large, elongate, the inner small, variable, a little longer than wide; 37 scale rows behind ear; 31 rows about narrow part of neck; 40 rows about body in axillary region; 32 scale rows about middle of body; 21 rows about base of tail; lateral scales parallel save in axillary region, the laterals larger than dorsals; preanals only moderately enlarged, the three outer pairs overlapping inner; subcaudal scales not or but slightly enlarged, not or but slightly differentiated in shape from the other caudal scales; 16-17 scales under the fourth toe; the inter-

calated series of scales on outer side of fourth toe not reaching to end of second phalanx; sole with only one or two somewhat enlarged tubercles anterior to the four heel plates; head slightly bulging behind eyes; ear opening moderate; limbs well developed, the hind leg reaching elbow when adpressed; the foreleg is contained in body length 3.3 times, the hind leg 2.3; the axilla to groin distance 1.8 times and the snout to foreleg distance, 2.5 times in body length.

COLOR (in alcohol): Above generally bronze, the scales showing certain metallic reflections, many scales showing a somewhat darker area; the top of head somewhat yellowish brown; a median lighter line dimly visible bifurcating on the nuchal, the line still visible to the prefrontals; a dorsolateral line extending from supraoculars, far on to the side of the tail; the scale row immediately above showing a fine row of black dots; dorsolateral lines follow outer edgs of fourth and inner third of the fifth row of scales, the rows separated, posteriorly at least, by eight scale rows; broad stripe on side of head somewhat deeper brown than top, growing gradually darker on neck, becoming almost black along side of body and tail; a lateral light line beginning on the presuboculars, forming at first a series of four more or less disconnected white spots, the last reaching the top of ear; line emerging from ear on the lower half continues above hind limb on to the tail, very strongly defined its entire length; lateral light line bordered below by a dark stripe; no sublateral light line; chin and lower labials flesh-colored; venter grayish growing bluish-gray posteriorly; a light line on the posterior side of femur; toes and feet lighter, the scales darker edged on toes.

COLOR OF FEMALE (paratype): Above very dark brown with the median light line bifurcating on nuchals continuing to rostral bordered by deep black lines, bronzy anteriorly, blue posteriorly; dorsolateral line narrow, running through middle of fifth scale row, greenish white with metallic reflections, bluish posteriorly; lateral stripe intensely black, more brownish on head; lateral light line prominent, wider anteriorly; otherwise similar to male.

VARIATION: In thirty-six specimens, on which I have complete data, the following scale variations are evident. Scales in a line from parietals to above anus, 55-59, with the following frequency: 55, three times; 56, four times; 57, twenty-one times; 58, seven times; and 59, once. Scale rows around the middle of body 30-32, with the following frequency: 30, eleven times; 31, eight times; 32, sixteen times. Upper labials 7-8, with the following frequency: 7, eighteen times; 8, eight times; 7 on one side, 8 on the other, ten

times. Postmentals invariably 2; postnasal invariably present; nuchals 1-2, one pair occurring twenty-six times; 2 pairs occurring two times; 2 on one side, 1 on the other, seven times. Invariably four supraoculars are present, three of which touch the frontal save in three cases, once on both sides of one specimen, twice on one side in two specimens. The frontal widely separated from the frontonasal in all but three cases. Once they were in contact; twice they were only narrowly separated. Subdigital lamellæ usually 16 to 18;

Measurements of *Eumeces inexpectatus* sp. nov.

No. / Museum	8232 K. U. M.	8233 K. U. M.	61632 M. U. M.	61634 M. U. M.	61754 M. U. M.
Snout to vent	66	62	79	73	77
Snout to fore leg	26	22	29	28	26
Snout to ear	15	14	17	17.3	17.1
Tail	reg.	reg.	128*	131	115*
Width of head	12	10	15	13.6	13
Length of head	13.2	11.4	15.2	15	14.7
Axilla to groin	36	30	38	37	41
Postanal tail width	9	7.5	9	10	9
Fore leg	20	19	24	21.5	22
Hind leg	28	25	33	31	31.5

* Partly regenerated. 8232, type; 8233, paratype; 61632, Michigan U. Mus., Hillsboro, Florida; 61634, near Gulfport, Pinelas county, Florida; 61754, Cabbage Key, Florida.

the count on two feet of the same individual rarely the same. Superciliaries varied between 8 and 10, 9 being the most frequent number.

The limbs invariably overlap; in old specimens the average is about 12 mm. The small scales separating the ear from the last labial and the lower secondary temporal show some variation; occasionally only one, usually two superimposed scales, the postlabial usually the largest.

In color the variations seem to be those dependent on age, and here as in the related *laticeps* and *fasciatus* there are three general "types" of coloration: those of the young, the adult male, and the adult female.

COLORATION OF YOUNG: (From University Michigan Museum No. 61629. From near Gulfport, Pinelas Co., Fla.) General ground color deep black; a very narrow median greenish white line running to nuchals, where it is slightly separated from the two diverging lines of the head; posteriorly, on back, median line blue, becoming a

deeper blue on tail, and is finally lost in the blue ground color of the latter part of the tail; dorsolateral line not touching diverging lines of head, arises separately on the first superciliary, continues with irregular edges over outer side of the supraoculars, then continues along side of body to tail, following the fifth scale row, generally greenish-white but becoming blue posteriorly; first four labials the creamy color of the chin and lower labials; lateral white line arises on the second loreal, passing through the presuboculars and under eye, crossing the last two labials to the top of ear, where it stops; the line then begins behind ear about middle and continues back to tail; lower part of the posterior labials dark; between the median and dorsolateral lines are two dim, narrow, bronze-colored lines on the edges of the second and third scale rows, visible as far as the tail, where they become blue; belly bluish gray, which color reaches on side to the black stripe, which is below the lateral line, at which the gray is slightly lighter so as to suggest a dim sublateral light line; tail deep blue, darker posteriorly, the under side of tail a more grayish blue; chin and breast cream color; a whitish line on posterior surface of hind leg.

A second young specimen, an immature male 48 mm. (University of Michigan No. 61631 from Hillsboro Co., Fla.) already begins to show the brownish coloration on the side of the head and the labial line the tendency to form white spots on the brown color of the posterior labials; the throat shows a slight salmon brown suffusion or tinge. In general the markings are the same as in the preceding specimen.

REMARKS: While, as pointed out, this form bears much similarity to *fasciatus,* it should in no sense be construed as a subspecies of either *fasciatus* or *laticeps* since the fact that it occurs through so wide a territory occupied by these two species and maintains its identity precludes such an association.

Unfortunately I have no data on the habits of the form, nor can I state whether the species is terrestrial or arboreal. The claws are somewhat intermediate in character between those of *laticeps* and *fasciatus.* One Michigan specimen bears the label, "caught under bark of a tree."

The species may be distinguished at once from either *fasciatus* or *laticeps* by the character of the median scales under the tail; these are not or but very slightly differentiated from adjoining scale rows, while in both of the other species the median series is very distinctly widened and the scales have a different shape from the adjoining

series. Details of the color pattern are likewise different. I have added a plate of typical *Eumeces fasciatus* showing three color phases for direct comparison with *inexpectatus*. The species may likewise be compared with a series of photographs of *Eumeces laticeps* (Plates XIX and XX) appearing in this same issue of the Science Bulletin in a paper entitled, *"Eumeces laticeps,* a neglected species of skink."

Like all of the known species of *Eumeces,* variation in head scales as well as scale rows and details of the markings must be anticipated at least to the extent to which they occur in any other species of *Eumeces* closely related or not. Many of the variations in the material examined have been pointed out, and other variations doubtless occur.

The material I have examined has not been exhaustive. Thanks to the courtesy of the authorities of the Michigan University Museum, and particularly Mrs. Helen T. Gaige, I have had the privilege of examining their extensive collection, which contains twenty-nine specimens of this new form from the following localities:

Nos. 65186, near Rock Hill, S. C.; 55058, Neuse river, New Bern, N. C.
Nos. 53693, 53694, 53698, 53700, 53701, 53702, University of Mississippi.
Nos. 61631, 61632, Hillsboro county, Florida; 56165, 56166, 56167, Fort Meyers, Fla.; 61629, 61634, near Gulfport, Pinelas county, Florida; 61628, near Clearwater, Pinelas county, Florida; 57717, Alachua county, Florida; 61754, Cabbage Key, Florida; 57717, 57720, Gainsville, Fla.; 61633, Long Key, Fla.; 44752, Caurey Island; 44717, 46800 (2 specimens), 52403, 52404, 52405, Chandler, Fla.

In the Kansas University Museum the following specimens are present: Nos. 776, 777, 778, 779, 780, Hillsboro county, Florida; 8232, 8233, Citrus county, Florida.

I have examined typical *Eumeces fasciatus* from many of these same localities, and *Eumeces laticeps* from practically a like number.

With the recognition of three distinct species of "five-lined" skinks in "Carolina" there arises a very nice taxonomic question as to the identity of the two Linnæan species *fasciatus* and *quinquelineatus,* the types of which, so far as I can learn, are no longer extant. As far as the Linnæan descriptions go they might apply with equal certainty to any of the three species—*fasciatus, laticeps,* or *inexpectatus.* Both of the Linnæan species are from "Carolina," and the fact that most subsequent authors have regarded them as synonymous does not preclude the possibility that they refer to two

separate species, one or neither of which may be the typical widespread form which, together with Schneider's *laticeps* and the present species *inexpectatus*, has until now borne the name of *fasciatus*.

In the present state of my study of these forms I am unable to offer any solution to this puzzle.

EXPLANATION OF PLATES.

PLATE XVII.

FIG. 1. *Eumeces inexpectatus* young female. Michigan University Museum No. 61629. Gulfport, Pinelas county, Florida. Lateral view, actual size, snout to vent, 67 mm.

FIG. 2. *Eumeces inexpectatus* same specimen dorsal view.

FIG. 3. *Eumeces inexpectatus* young male. M. U. M. No. 61631. Hillsboro County, Florida. Actual size, snout to vent, 50 mm.

FIG. 4. *Eumeces inexpectatus* adult male. Type. Kansas University Museum No. 8232. Citrus county, Florida. Actual size, snout to vent, 66 mm.

FIG. 5. *Eumeces inexpectatus* adult female. Paratype. K. U. M. No. 8233. Citrus county, Florida. Actual size, snout to vent, 62 mm.

PLATE XVII.

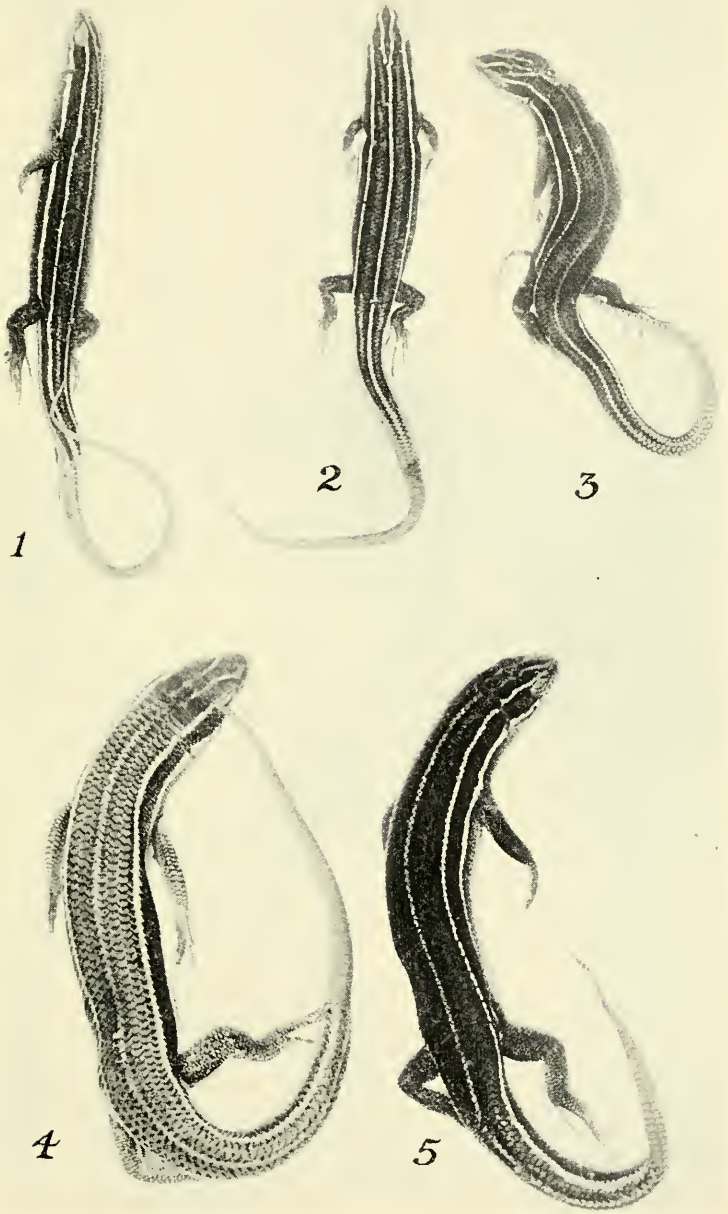


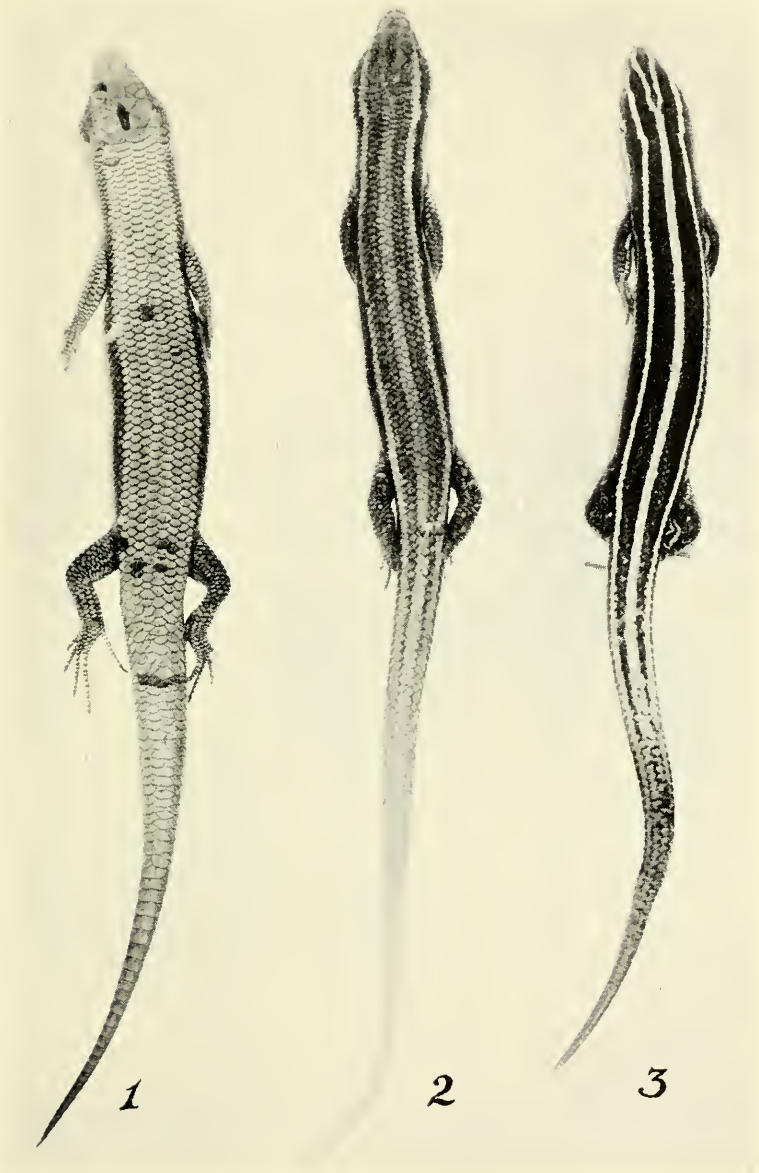
PLATE XVIII.

FIG. 1. *Eumeces fasciatus.* Adult male, old. Imboden, Ark. K. U. M. No. 11359. Size × 1.

FIG. 2. *Eumeces fasciatus.* Adult male, transitional coloration. Imboden, Ark. K. U. M. No. 11355. Size × 1.

FIG. 3. Adult female, typical coloration. Imboden, Ark. K. U. M. No. 11352. Size × 1.

PLATE XVIII.



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VOL. XX] MAY, 1932 [No. 14

Eumeces laticeps: A Neglected Species of Skink.

EDWARD H. TAYLOR.

THE reëstablishment of the form long known as *Eumeces laticeps* Schneider may come as a surprise to the herpetologists, who have attempted to separate the wide-headed form occurring throughout the southern part of the United States from the typical *fasciatus*, and have given up the task as hopeless.

The older, less critical herpetologists, Holbrook, Harlan, Green, and many others, recognized the large form, *laticeps* Schneider: (*erythrocephalus* Gilliams), chiefly on the basis of size, and color of the head; later ones have considered it conspecific with *fasciatus* largely on coloration and markings.

The confusing fact has been that the two species *fasciatus* and *laticeps* go through the same general type of development. They both have practically the same color pattern; the old females retaining more of the color pattern than the males in each case. The males acquire a widened head with a red or red-brown coloration; the old females have a less widened head and develop no, or only a slight brownish, coloration instead of a reddish coloration.

Another fact that has added to the confusion is that both forms agree in having one postmental and a postnasal. *Fasciatus has* the generic habit of varying in these basic characters, as well as in the relationship of the frontonasal and the frontal, and the resultant effect on the prefrontals; in *laticeps* these characters are especially stable in comparison.

An examination of other characters, however, seems to show that in addition to the enormous difference in size the following characters will serve to distinguish *laticeps* from *fasciatus* in any given locality. One, of course, must not overlook the marked tendency to variation.

1. Usually a higher number of scale rows about the body.
2. The presence of eight (usually) instead of seven (usually) upper labials, the first five anterior to the "subocular" labial. (The last labial is largest in both forms.)

3. The tendency of the lower secondary temporal to enter the ear or be very narrowly separated from the ear; and only a single postlabial to separate the last labial from the edge of the auricular opening with usually a single very small scale superimposed above posterior part of postlabial.
4. The union of the prefrontals and consequent separation of frontal and frontonasal.
5. Wider supraoculars.
6. Higher labials; especially the subocular, in proportion to its length.
7. Longer limbs.
8. Shorter axilla to groin measurement.
9. Wider head proportionally in males.
10. A larger seventh labial.
11. Lower secondary temporal of very different shape.

Certain other characters, which, while perhaps not as important as the preceding, seem to give additional warrant for their separation:

1. A larger number (3-4) enlarged tubercles on sole of foot preceding the larger heel tubercles.
2. The presence of an added row of scales along the fourth toe reaching to, or near to, the distal phalanx.
3. A tendency for five postsuboculars to be present.
4. An arboreal habitat.
5. Larger, thicker claws.

It is highly probable that individuals may be found that will vary in one, possibly more, respects from these listed characters, but no specimen will vary in all of them.

As regards size of specimens, the difference between *laticeps* and *fasciatus* is very probably evident upon hatching. The youngest specimens of each of the two species I have at hand are Okla. Mus. No. 1885 *laticeps,* and 947 and 72184 *fasciatus.* The former is very young, probably just hatched as shown by the condition of the umbilicus and the greatly broadened character of the interparietal. The following list of measurements show the difference between *laticeps* and obviously older forms of *fasciatus.*

	Fasciatus, No. 72184.	Fasciatus, No. 947.	Laticeps, No.1885.
Head to vent	26	35	30
Axilla to groin	13.5	17	14
Width of head	5	5.1	7.1
Length of head	6	7.5	8
Width of body	4	5	8
Hind leg	12	14	14
Postanal tail width	1.6	3.1	3.1
Hind foot	6.0	6.5	8.0

One of the most conspicuous differences is in the claws, which are thicker, longer, and curved strongly downward, suggesting the

possibility that the young are better climbers and are probably arboreal in habit from the beginning, instead of later taking to the arboreal habitat as has been proposed by many authors.

The variation of scalation that obtains in the two species in a given locality is shown in the following series from eastern Oklahoma. In *laticeps* the average number of scale rows is 32. One specimen shows 34, while two show 31. In the same lot all but one have 8 upper labials, 5 anterior to the subocular; the single specimen, showing only 7 upper labials with 4 preceding the suboculars, agrees in all other respects and at the same time is the one having 34 scale rows. It is from the same locality (Lattimer county, Oklahoma) as are several others of the series.

A series of ten *fasciatus* from Lattimer county, Oklahoma, show the following variation: Scale rows 26-30, of which 7 are 30, one 26, one 27 and one 28. Eight of these have 7 upper labials, 4 preceding the subocular, while 2 have 8 upper labials with 5 preceding the subocular.

In the number of postsuboculars (separating the labials and temporals from eye) there are usually 5 in *laticeps;* thus in 22 times (counting both sides of the 11 specimens) 5 occurs 10 times, 4 occurs 6 times, and 6 occurs once. In the *fasciatus* series of ten, 4 occurs 19 times, 5 occurs once.

In the same *laticeps* series the number of nuchals varies about equally; in 22 times (counting each side of the series of 11) 1 nuchal occurs 13 times and 2 occurs 9 times; 3 specimens show 2 pair, 5 showing 1 pair. In the *fasciatus* series of 10, 1 nuchal occurs 9 times, and 2 occurs 11 times; 4 specimens show 2 on each side; 3 1 on each side.

As regards the postmental, in the *laticeps* series 2 was invariably the number, and the postmental was invariably present, while in *fasciatus* 2 specimens have the postmental completely fused, with no evidence of its double character. The postnasal is invariably present.

In a series of 8 *laticeps* from Imboden, Arkansas, received by exchange from Byron Marshall, the scale rows varied from 30-32, 30 occurring 5 times, 32 occurring 2 times, 31 once. The upper labials were 8, save that two specimens showed 7 at one time; 2 postmentals invariably; 1 postnasal, save in two specimens that had the anterior loreal segmented and the postnasal fused to the lower moiety.

The postsuboculars were less constantly 5 in number; in 16 times

(counting both sides of the 8 specimens) 5 occurs 7 times, and 4 occurs 9 times.

One other character is that the entire series of *laticeps* average 2 or 3 more lamellæ under the fourth toe, the usual number being 17-18, 18 occurring the greater number of times; in *fasciatus* the numbers 15-16 are usual, 15 occurring the greater number of times.

A single specimen of *laticeps* from Gentilly, La., in the Ottawa University, Ottawa, Kan., shows the peculiarity of having a portion of the subocular segmented, leaving the pre- and postsubocular series continuous; the intercalated scale, the largest of the series, is present on each side and appears to be a normal condition. Otherwise it does not differ from typical *laticeps*.

A question might arise as to whether the two forms interbreed. In the material examined I find no specimens that could not be separated into their proper species on the basis of the character combinations suggested above. It would appear, after an examination of the internal sex organs of a number of the specimens, that *laticeps* does not begin to breed until a size is reached that is as great or greater than the adult *fasciatus*, and that size alone might serve as the factor to prevent interbreeding.

The paucity of young specimens of *laticeps* in collections is a matter of no little interest, but is strongly suggestive of the fact that eggs are laid in trees and that the young are arboreal from the beginning as is suggested also by the claws (*vide supra*). It is highly probable that it is this lack of young specimens of this species in collections and the abundant presence of *fasciatus* in collections from the same localities that has been partially responsible for the confusion of the two forms for the past half century.

In the eastern part of the range of the species there is a tendency for it to have seven lines, the extra pair being sublateral, beginning low on side of neck and continuing to the groin. This line persists in females and in all save old males. In the western part of the range this extra line is wanting. A number of other differences are in evidence. The transitional coloration varies and there are certain scale variations. It may be possible after larger series are examined to recognize an eastern and western form.

It is probable that Cope's *E. polygrammus*,[1] Colonels Island, Liberty county, Georgia (U. S. N. M. No. 4156), is a specimen of this form.

1. Cope, E. D.: Ann. Rept. U. S. Nat. Mus. 1898 (1900), p. 637, 638.

Schneider[2] does not give a type locality, but it is highly probable that the type specimen came from the east coast region of the United States and that *polygrammus* is a direct synonym of this form.

The plates give photographs of specimens from the eastern part of the range, as well as from the west. Unfortunately the photographs do not show the same relative reduction, so actual size is recorded for each specimen.

2. Schneider: Hist. Amph., II 1801, p. 189.

EXPLANATION OF PLATES.

PLATE XIX.

FIG. 1. *Eumeces laticeps* Schneider. Michigan University Museum No. 67792. Pigeon River, Butte county, Alabama. (Seven-lined form. Adult female, 93 mm. snout to vent.)

FIG. 2. *Eumeces laticeps*. M. U. M. No. 67793. Houston county, Georgia. (Seven-lined form. Adult female, 87 mm.)

PLATE XIX.

PLATE XX.

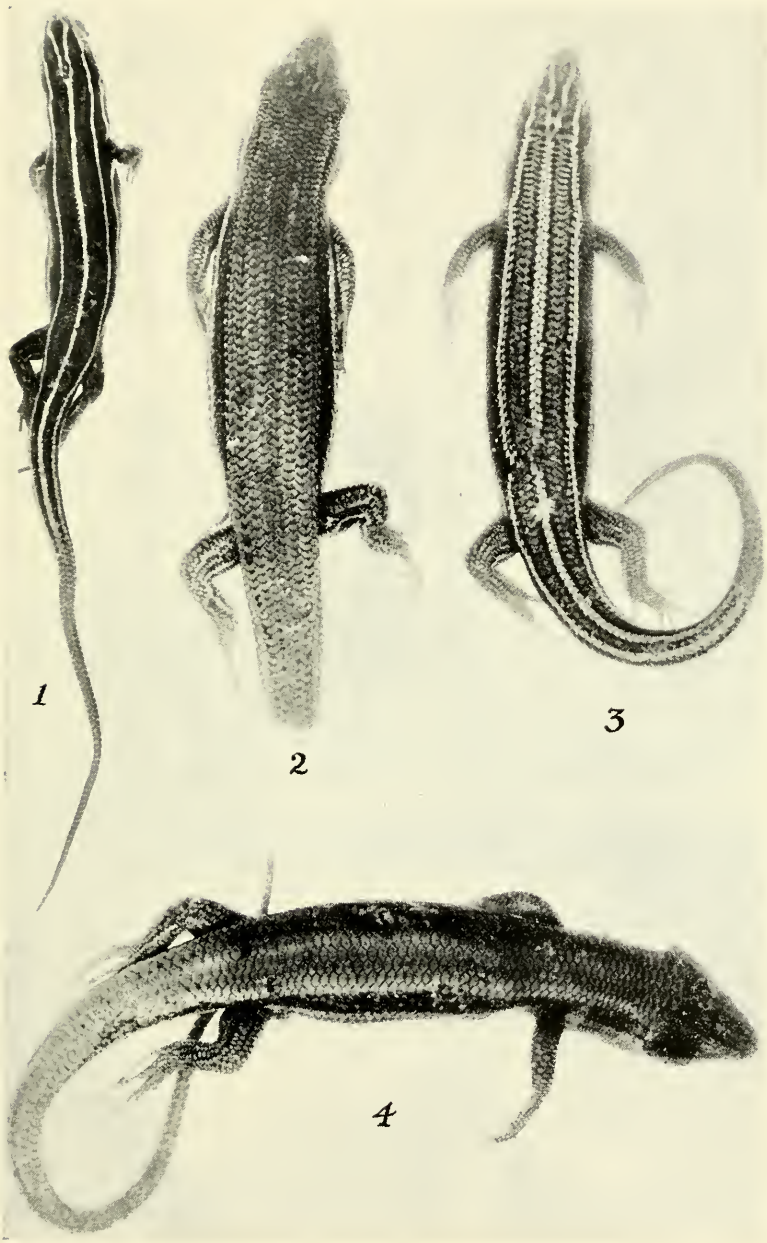
Fig. 1. *Eumeces laticeps* young. M. U. M. No. 57717. Micanopy Road, Florida. (Seven-lined form, 54 mm.)

Fig. 2. *Eumeces laticeps*. M. U. M. No. 56607. Alachua county, Florida. Adult female, containing 14 undeveloped eggs. (Seven-lined form, 95 mm.)

Fig. 3. *Eumeces laticeps*. M. U. M. No. 56686. Hanover, Ind. (Five-lined form, 84 mm.)

Fig. 4. *Eumeces laticeps*. Oklahoma University Museum No. 7265. Delaware county, Oklahoma. (Five-lined form, 112 mm.)

PLATE XX.



THE UNIVERSITY OF KANSAS
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A Comparative Study of the Skull in the Genus *Eumeces* of the Scincidæ (a Preliminary Paper).

R. H. KINGMAN,
Professor of Zoölogy, Washburn College.

INTRODUCTION.

THE study of the skull of this genus presents the following problems for investigation: (1) the homology of the parts of the skull; (2) the variations in some of the bones and their position; and (3) the fusions of the bones in the various regions.

This work was done at the suggestion and under the direction of Dr. E. H. Taylor and Dr. H. H. Lane, of the Zoölogy Department of Kansas University. Charles Bunker, curator of Dyche Museum, has very kindly lent much material, most of which was collected by Doctor Taylor.

OBSERVATIONS.

A complete loss of any one bone was not observed in the study of this series of skulls, but a decided reduction was observed in the case of the postorbital bone.

In introducing the characters of the individual bones it might be well to consider the general characteristics of the skull of this genus. The characteristics are as follows:

(1) The post-temporal vacuity is present in the occipital portion of the skull between the parietal-squamosal and the paroccipital elements.

(2) The supratemporal vacuity or fontanelle is between the parietal, squamosal, postfrontal and postorbital. This is variable with the species, as some show almost none and others show it very clearly.

The following description is based on the skull of *Eumeces obsoletus;* later a comparison will be made with the various species studied.

17—3668

(1) FRONTAL. The frontal bones are two in number located between the orbits of the eye and beneath the frontal and frontoparietal scales of the dorsal surface of the head. In the median line each is flattened except for slight depressions, while along the sides extending from the orbit to its anterior extremity there is a beveled edge that forms the support for the supraocular scales above the eyes. Anteriorly it articulates with the nasal bone, to which it unites along a crescentic suture from the median line. In the anterior lateral portion of the orbit it is in contact with the prefrontal. A small maxillary process is found on the anterior lateral surface where it comes in contact with the maxillary bone lateral to the nasal suture. Posteriorly it meets the anterior edge of the parietal bone. Laterally along the margin of the orbit it is in contact with the postorbital.

(2) PARIETAL. The parietal is a single median bone located beneath the parietal, interparietal and nuchal scales of the surface of the head. This is composed of a more or less triangular body which has within it, in the median line, a small opening, the parietal foramen for the organ of the same name. The opening is a little anterior to the middle of the body of the bone. Extending posteriolaterally are two processes, the squamosal processes. These are curved and slightly recurved away from the median line. In the median line at the posterior border there is a prominent notch into which fits a membrane and a small knob-like element that suggests the location of an "interparietal." Lateral to this notch two posteriorly directed processes extend to meet the occipital bone. Along the median and posterior border of the parietal there is a marked ridge which is continuous with an obliquely directed surface for the attachment of the neck muscles of the skull.

On the ventral surface of the body of the parietal bone and in direct line with the parietal foramen are two sliverlike processes which extend down almost at right angles to the remainder of the bone. These articulate with the epipterygoid and with the latter enforce the upper jaw and gave rigidity to the membrane surrounding the brain.

The parietal articulates with the following: frontal, squamosal, postfrontal, paraoccipital, and epipterygoid bones.

(3) SUPRAOCCIPITAL. The supraoccipital is an unpaired median element fused, in the adult, at the basal part of the skull with the exoccipitals, paroccipitals and some of the bones of the otic capsule. The posterior and lateral limits of this element cannot be distin-

guished in the adult. It probably forms a median raised area from the foramen magnum forward to the median line of the parietal as well as a slight flattened process on either side of raised median portion. These flattened processes contain the median portions of the semicircular canals which are visible from the dorsal surface.

(4) EXOCCIPITALS. The exoccipitals form the sides of the foramen magnum and the lateral pieces of the occipital condyle. The occipital condyle is composed of three parts; the median piece is the basioccipital while the lateral two are exoccipital parts. The main portion of this bone is inseparably fused with the paroccipitals. The lateral processes articulate with the quadrate, parietal, squamosal and supratemporal bones.

(5) BASIOCCIPITAL. The basioccipital is placed ventrad to the foramen magnum forming about thirty degrees around that aperture. The general outline of this bone is suggestive of the shape of a diamond with its long axis running from left to right. Along the anterior and lateral border of this diamond-shaped area the basioccipital articulates with the basisphenoid by an irregular suture. In the adult a slight depressed groove remains, separating the basioccipital and the exoccipital bones.

(6) BASISPHENOID. The basisphenoid is located just anterior to the basioccipital, with which it articulates by an irregular suture. The body of this bone is more or less triangular with the base posterior and its apex extending to the interorbital rostrum anteriorly; which is in the region of the presphenoid. Extending laterally from the body are two fan-shaped processes, the pterygoid processes, which form broad but thin facets for the articulation with the pterygoid as it moves with the movement of the lower jaw.

(7) PROÖTICS. The proötics are two bones between the basisphenoid, basioccipital, paraoccipital and supraoccipital bones. In the adult the sutures are not clearly visible.

(8) PARASPHENOID (presphenoid). The parasphenoid is continuous with the basisphenoid and extends forward to the prevomers and palatines. This bone has been homologized with the vomers of mammals. This element in these lizards is cartilaginous and forms the ventral support for the interorbital septum. The space in which this is located is called the interpterygoidal space. It is impossible to see where it unites with the ethmoid or sphenethmoid in prepared skulls.

(9) QUADRATES. The quadrates are two conspicuous bones at the posterior and lateral surfaces of the skull, articulating directly with the pterygoid on the ventroanterior surface; with the paroccipital, supratemporal and squamosal on the dorsal and posterior border. Each quadrate is concave on its ventral posterior surface, while it is convex anteriorly. There is a double articular surface for the movement of the lower jaw; the tympanic membrane and the columella are parts articulated with this bone.

(10) PTERYGOIDS. The pterygoid bones are long (10 mm.) and extend about half the length of the entire skull on the ventral surface. The anterior portion may be considered the body which bears teeth upon its ventral median surface. These teeth are placed in depressions and seemingly in two rows of irregular size and range from six to ten on each side. The teeth are rather heavy and are blunt at their extremity. This bone connects anteriorly with the palatines, laterally with the ectopterygoids and the jugals, while posteriorly it articulates with the quadrate, and about its middle with the basisphenoid. (The posterior process is a thin knife-bladelike process passing from the basisphenoid to the quadrate.) Its articulation with the ectopterygoid is by a broad, flat surface directly under the ectopterygoid bone. The ectopterygoid, or os transversum, with the pterygoid process together produce the posterior bar, the limit of the postpalatine vacuity.

(11) ECTOPTERYGOIDS (*os transversum* or *transpalatines*). There are two ectopterygoids, and they extend from the maxillary and jugal bones to the pterygoid, and these are the only bones with which they articulate.

(12) EPIPTERYGOIDS. The epipterygoids are a pair of sliver-shaped bones extending from the dorsal surface of the pterygoid to the parietal bone. The union with the pterygoid bone is made by means of a socket in which the enlarged end of the epipterygoids fit. The other end of the epipterygoid is attenuated and meets a sliver-like process extending down from the parietal bone, with which it articulates.

(13) PALATINES. The palatines are two in number and meet in their anterior portion. There are two plates that make up this bone, one located dorsally and one ventrally; both plates are united along the lateral margins. The ventral plate is nearly flattened and is continuous with the broad palatine process from the alveolar surface of the maxillary bone. Posteriorly it is continuous with the

anterior surface of the pterygoid. The dorsal plate has a somewhat curved surface as well as a double curved margin along the median line. At the anterior surface of this plate the left and right palatine bones come in contact. This contact is directly posterior to the prevomer teeth, which project back a little distance in the median line. The dorsal plate articulates with the prevomers anteriorly while posteriorly it unites with the pterygoids as does the other. The space between the dorsal and ventral plates of the palatine bone produces a passage for air down the sides of the prevomer to the nasal passage.

(14) PREVOMER (*vomers,* but not homologous with the vomer of mammals). The prevomers are represented in this form by a single inseparable piece in the adult, which has all evidence of being composed of two distinct parts united in a groove in the median line. At the posterior end of the plate near the median groove is found a pair of toothlike processes that may be considered the homologue of prevomerine teeth. Extending from these processes forward is a gentle ridge which becomes flattened near its articulation with the premaxillary bones. At the extreme anterior end in the median line is a tubercle with a cartilaginous tip and a slight depression on either side. Two openings may be seen along the lateral margin next to the maxillary bones; these seem to connect with a cavity in the prevomers and may be the opening to Jacobson's organ. Posterior to these openings and along the margin in the maxillary bone is a slitlike passage which is continuous with the nasal passage above.

(15) PREMAXILLARY. The premaxillary bones are two in number and are located on the anterior surface of the upper jaw. There are two distinctly separate bones in this form. Left and right elements are not equal in size as the right one is slightly larger, having four teeth while on the left side only three are present. The premaxillary bones articulate dorsally and posteriorly with the nasal bones, laterally and posteriorly with the maxillary bones and ventrally with the prevomers. The dorsal median processes form a separation between the external nares.

(16) MAXILLARIES. The maxillary bones are elongated bones that constitute the outer edge of the upper jaw and bear the majority of the teeth in this region. They form the posterior and lateral margin of the external nares and the lateral margin of the postpalatine vacuity and lateral margin at anterior edge of the orbit of the eye. The maxillary articulates with the following bones: anteriorly with

the premaxillaries, prevomers, nasals and septomaxillæ; posteriorly with the frontals, prefrontals, lachrymals, jugals, and ectopterygoids; and medially with the palatines. The outer edge of the ventral surface of the maxillary bone is raised into a flange, while the inner surface is on a lower level and is continuous with the palatine bone. The nearly cylindrical teeth are fastened to the lower surface of this bone and also to the raised flange, making the teeth pleurodont in attachment. Smaller teeth are visible on the lower surface and are the replacing teeth for worn-out older ones.

(17) JUGALS. The jugal bones are narrow bones forming the angle of the upper jaw and the outer and posterior margin of the orbit. The entire shape suggests that of a hockey stick. The straight handle-shaped portion is fastened near its end along the edge of the orbit, making up part of the lateral border. The ventral part is curved and meets the maxillary at its posterior end. Here it becomes narrowed to a very thin process that is lodged between the maxillary, ectopterygoid and lachrymal bones. On its dorsal and posterior end it articulates with the postfrontal, postorbital, and squamosal. On the ventral surface of the jaw a posterior lateral spine is seen as though it were a continuation of the upper jaw.

(18) SQUAMOSALS (*paraquadrates* of Gaupp). The squamosals as here identified articulate in front with the jugal and postorbital, at about the middle of its extent with the parietal, and posteriorly with the quadrate, supratemporal and paroccipitals. It is a flattened curved bone forming the outer border of the dorsal surface of the skull. This bone is undoubtedly not a quadratojugal, as the lateral temporal vacuity is not formed because of the disappearance of the lateral arcade.

(19) SUPRATEMPORAL (*supramastoid,* suprasquamosal, tabular of Noble, or *squamosal* of Gaupp, *epiotic, postparietal*). These bones are two small, insignificant, sliver-shaped bones located between the squamosal and parietal bones laterally, while posteriorly they articulate with the quadrate and paraoccipital processes. They are never in contact with the postorbital and postfrontal bones in this form. In disarticulated skulls and in some prepared skulls there is an additional element that may be an atrophied tabular or quadratojugal. In most skulls it is represented as an aperture on the quadrate near its articulation with the squamosal and supratemporal at the place of its articulation.

(20) POSTFRONTALS. The postfrontal bones form the posterior border of the orbit. A thin, narrow piece extends along the margin of the frontal bone and the orbit; the body of this bone is a nearly leaf-shaped element in contact with the parietal medially and with the postorbital laterally and with the jugal on its anterolateral surface at the posterior lateral boundary of the orbit. Its posterior extremity is variable both on left and right sides on the same skull as well as in different skulls.

(21) POSTORBITALS (*postfrontals*—Gaupp). The postorbitals, two small bones in this skull, do not form part of the orbit nor part of the edge of the skull. They articulate with the postfrontal, squamosal, jugal and by a slight point touch the parietal on one side in one skull studied. Each borders on the fontanelle or vacuity on the dorsal surface of the skull. Its variation will be brought out in the comparisons of the various species to follow. Ventrally it presents a triangular appearance.

(22) PREFRONTALS (*lachrymals* of mammals—Gaupp). The prefrontal bones are located at the median anterior end of the orbit; they are inseparably united with the lachrymal bone, articulating with the frontal, maxillary and lachrymals. A part of the suture remaining suggests the place of union with the lachrymal. A marked ridge and a groove just below shows the point of attachment of the small supraocular bone, which is found in careful preparations. It is easily removed with the skin unless extra care is used.

(23) LACHRYMALS. The lachrymal bones are at the anterior extremity of the orbit and are, as previously stated, fused in the adult with the postfrontals. Each is characterized in this form by having a foramen penetrating it from the orbital side into the nasal cavity, and articulates with the maxillæ, jugals, and prefrontals.

(24) NASALS. The nasal bones form part of the septum between the external nares as well as part of the posterior boundary of the same. These bones are thin plates nearly ovoid in shape, with their anterior median extremities covered by the dorsoposterior projections of the premaxillary bones. Posteriorly they articulate with the frontals and laterally with the maxillæ. The small septomaxillæ probably do not come in contact with this element, but do with the maxillary bone.

(25) STAPES. The stapes are thin cylindrical bones that fit into the foramen ovale of the paroccipital process. They pass out posteriorly to the quadrate, where they seem to be strengthened in

their position by this bone and by the tympanic membrane on the outer surface of the head.

A COMPARATIVE STUDY OF THE EUMECES.

The following species of *Eumeces* were studied and compared with *Eumeces obsoletus* just described: *Eumeces fasciatus*,[1] *Eumeces septentrionalis, Eumeces tetragrammus, Eumeces chinensis, Eumeces longirostris, Eumeces schneiderii pavimentatus*,[2] *Eumeces skiltonianus, Eumeces humilis*, and *Eumeces laticeps*.[3]

In this comparative study we will discuss the separate bones of the skulls of the different species.

The frontal bone in all forms has comparatively the same shape, but there are some variations. In *Eumeces fasciatus, laticeps, longirostris, skiltonianus*,[4] *schneiderii pavimentatus, tetragrammus* and *humilis* it touches the maxillary bone along its anterior lateral extremity. In the other three species it does not come in contact with the maxillary bone.

In *Eumeces septentrionalis* alone there was evidence of a fusion of the parietals. This may be an individual variation and may not occur regularly even in this species. The posterior median notch is very prominent in *obsoletus* and *skiltonianus* while it is decidedly insignificant in *schneiderii pavimentatus* and *chinensis*. Associated with the notch on either side are two posterior projections that fit into the occipital bones; these are long and extremely pointed in *obsoletus*, less pointed in *fasciatus*, long and blunt at the tips in *skiltonianus* and nearly lacking in *chinensis* and *schneiderii pavimentatus*. The lateral edges of the body of the parietal are more concave in those forms where the fontanelle is most striking; thus in *schneiderii pavimentatus* its outline suggests an hourglass, while in *fasciatus* the lateral boundaries are nearly parallel and no fontanelle is evident. The posterior lateral projections are broad and thick in *chinensis* and *skiltonianus* while in *tetragrammus* they are narrow and delicate. The parietal foramen is located anterior to the middle of the parietal bone in *schneiderii pavimentatus;* in *skiltonianus* and *longirostris* it is slightly posterior to the middle of the bone.

In *laticeps* a small element, here called the interparietal for want of a better name, is very prominent and fills the median posterior notch.

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1. In *sensu strictu*.
2. Identified by Dr. Robert Mertens.
3. According to Dr. Edward H. Taylor.
4. This is *gilberti* of Van Denburgh, thought by Dr. E. H. Taylor to be possibly distinct from *skiltonianus*.

In the occipital region the occipital condyle is composed of two exoccipital elements and a basioccipital as was seen in both *schneiderii pavimentatus* and *chinensis,* while all the rest have lost their demarcation of elements in this region.

The paroccipital has its limits represented anteriorly by sutures on the dorsal and lateral surfaces; at the sides of the foramen magnum in *Eumeces fasciatus* and *schneiderii pavimentatus;* in all of the rest there is a ridge that marks its union with the supraoccipital. The proöties are represented at the anterior end and lateral to the supraoccipital; where in *schneiderii, fasciatus* and *septentrionalis* there is a remnant of a suture, the rest all show a ridge at this place of union.

The basioccipital portion of the occipital condyle is very distinct in the two forms previously mentioned; the rest of the skulls do not show a clear division, although in *Eumeces fasciatus* there is a marked groove extending from the condyle to the lateral prominences which undoubtedly represents a former line of fusion. From the lateral prominences a ridge is evident, passing about half way through the bone in all of the forms studied; it is the most pronounced in *chinensis,* where it forms a marked ridge. The rest of the bone inclines from the ridge both forward and backward. In *septentrionalis* this is but a slight elevation without any clear demarcation from the rest of the bone. The shape of the basioccipital is more nearly diamond-shaped in *chinensis* and *obsoletus* than in the rest. In these merely a suggestion of this shape, remains, as the suture uniting the basisphenoid becomes irregular or broadly united with it as in *septentrionalis, chinensis, humilis, skiltonianus* and *longirostris.* In *skiltonianus* the suture has become obliterated except near the midventral line, where it appears as a slightly wavy transverse line.

The basisphenoid unites directly to the basioccipital at its posterior end and the body of this bone has a broad base in *Eumeces schneiderii pavimentatus* with the lateral limits extending to the broadest part of the basioccipital; in all of the other species of the group studied except *obsoletus* the posterior limiting suture is nearly transversely directed. The fan-shaped pterygoid processes are variable. They are broadly attached to the body in *chinensis, schneiderii* and *obsoletus.* In all remaining skulls except *skiltonainus* the attachments are long and delicate, suggestive of the make-up of the entire skull. The alisphenoid at the side of the body helps to produce a groove extending back to the region of the quadrate. In

obsoletus, longirostris, skiltonianus and *humilis* the sutures are obliterated by fusion. Whether this is characteristic of the species or merely the age of the specimen could not be ascertained. The anterior limit of this bone extends forward into a slight projection, which is continuous with the presphenoidal rostrum; this anterior piece is quite elongated and bifurcated in *Eumeces,* while in *obsoletus* it is bifurcated but not elongated. In *longirostris* this median piece is decidedly short and has an extra, median, short lobe.

The parasphenoidal rostrum (parasphenoid) is cartilaginous in all forms and therefore not clearly comparable.

The quadrate is quite different in thickness, undoubtedly to strengthen the lower jaw. In *Eumeces chinensis* the quadrate is the heaviest bone. The lateral concavity produced by the thin bony plate extending from the mandibular condyle to its attachment to the paroccipital process produces the lateral boundary of the posterior part of the skull. The quadrate presents a conspicuous aperture in some skulls, as in *fasciatus, septentrionalis* and *brevilineatus.* However, in *schneiderii pavimentatus* there is in this region a small oval bone or plate that may be a dermal piece covering this aperture. This may be a remnant of former existing parts. In all other skulls studied neither this element nor the aperture was seen. Whether this was a lack of preparation or a specific character could not be ascertained.

The pterygoid in all these forms differ considerably, both in variation of the teeth and in its lateral connection. In *Eumeces longirostris* there are only two teeth on each side of the *pterygoid.* In *fasciatus* there is a single row of six teeth, while in *schneiderii pavimentatus* there seems to be an area of attachment of the teeth with a clearly defined row toward the outer edge of the area. In some forms the ectopterygoid process of this bone is greatly elongated, while in others it is very short. In *Schneiderii pavimentatus,* and *obsoletus, chinensis,* and *septentrionalis* this process extends to connect with the jugal bone at its extremity. In *fasciatus, longirostris* and *humilis* there is quite a long process, but it is not in contact with the jugal. In *tetragrammus* it is quite short.

The ectopterygoid is grooved in those forms with long pterygoid processes, and in that case this process fits into a groove which extends to the border of the jaw. In *chinensis, schneiderii pavimentatus* and *obsoletus* the ectopterygoid is considerably thicker than in *fasciatus.*

The palatines are of interest in this group because the left and

right halves are in contact along the median line. In *chinensis* the dorsal plates are in contact in the median line for about two-thirds of their way where they separate abruptly to unite with the anterior end of the pterygoid. In *schneiderii pavimentatus* the palatines resemble the condition in *chinensis* except that possibly a third of their median border is in contact, while in *obsoletus* they barely meet at the anterior part under the prevomerine teeth. The significance of the dorsal plate is not seen from a prepared skull, but in a disarticulated state it is clearly evident that this is most important, since it forms a tubelike passage for the air from the side of the prevomers to the mouth cavity. This passes by way of the internal nares which open beside the palatines rather than in the region of the prevomers. The most noticeable variation of this bone is in the inner margin of the ventral plate. In *longirostris* its margin is a regular S-shaped curve extending from its anterior to its posterior limit. In *humilis* it is very similar, but its contact is much more abrupt. In *fasciatus* there is a pronounced point or shoulder on the anterior median edge of the ventral plate. This is unique among the species studied, although there is an approximation to this condition in *chinensis*. A foramen is visible on some skulls from the ventral surfaces, passing from the orbit into the nasal cavity. In *chinensis, fasciatus, humilis, skiltonianus,* and *septentrionalis* it may be seen from the ventral surface, while in the rest it may be too small and at such an angle that it is not evident from either surface.

The prevomers bear toothlike posterior projections in all forms studied, but these are not constant in the number present. In *Eumeces schneiderii pavimentatus* two posteriorly directed projections are present on either side, making four altogether in this region, while all of the rest have only two. In *septentrionalis* the bone is almost as wide as it is long, while in *schneiderii pavimentatus, obsoletus, skiltonianus* and *longirostris* it is about twice as long as it is broad, as seen from the ventral surface. The apertures that seem to be the internal nares or choanæ are very evident from the ventral surface, but are probably openings to Jacobson's organ. Just posterior to these apertures on *skiltonianus* and *longirostris* is a pronounced depression that passes from the median line to the edge of the mandible. This marks the posterior limit of Jacobson's organ in the internal capsule within this bone.

The premaxillaries are two in number and are usually unequal in size and usually bear an unequal number of teeth. In only *Eumeces chinensis* are the teeth of the same number on both sides,

three in each bone. Even here the two bones cannot be said to be equal in size on both sides. In *longirostris* there are two teeth on the left side and three on the right side, all the rest of the species studied had three on the left side and four on the right side. To make room for the difference in teeth on the two sides the suture dividing left and right is merely turned farther over on the left side than on the right.

The maxillary bones do not differ greatly in the various species. The maxillary bones are in contact with the frontal bones in all forms studied except *Eumeces chinensis* and *septentrionalis*, where the prefrontals and nasals intervene. In the skull of *Eumeces humilis* studied, the maxillary bone is in contact on one side and not on the other side. The teeth are variable in the various species, averaging about twenty-two teeth to each side.

The jugals have a wide variation, particularly at the posterior angle of the jaw or at the broadest part of the head near the orbits of the eyes. There is in three species—*obsoletus, schneiderii pavimentatus* and *skiltonianus*—a posterolateral point on the jugal that suggests the place of continuance of some element in the past. In its posterior limit we see that the jugal connects with the squamosal in *tetragrammus*, while in *obsoletus, humilis* and *septentrionalis* they are barely in contact. In *schneiderii, fasciatus* and *skiltonianus* the edge of the jugal is separated from the squamosal by the slight intervening gap of the postorbital. In *longirostris* and *chinensis* the jugal does not articulate with the squamosal, as the postorbital lies between them.

The prefrontals are in contact with the nasals in some forms, while in the rest the frontal intervenes and is in contact and possibly fused with the lachrymal bones. It is to the lateral anterior border that the supraoculars are attached, as can be seen in carefully prepared skulls.

The lachrymals are inseparably fused with the prefrontals, though probably separate in younger forms. In most of the skulls studied the lachrymal is in contact with the jugals.

The nasals articulate with premaxillaries, maxillaries and frontals in *Eumeces obsoletus*, but are also in contact with the prefrontals in *chinensis, fasciatus, laticeps, septentrionalis* and *humilis*.

The postfrontal bones are modified with the appearance of a vacuity or fontanelle on the dorsal surface of the skull. In skulls without a fontanelle this bone is greatly elongated posteriorly, while in skulls with a fontanelle this bone is either shortened posteriorly

or narrowed laterally. Although the skull of *skiltonianus* has a fontanelle or vacuity this bone is similar to other solid-skulled forms. In this specimen the postorbital seems to be shortened or lacking. In *chinensis, septentrionalis* and *tetragrammus* the skulls are solid with no sign of opening or fontanelle, while in *laticeps* there is a suggestion of an opening on one side, as if it were a remnant of a fontanelle. In *skiltonianus* this bone is broad and long and shows no sign of shortening, but a fontanelle is present as if formed by the partial disappearance of the postorbital at the posterior end. In *obsoletus* the two sides are variable, and on one side it is greatly shortened while on the other side it is an irregular sliver between the squamosal and the parietal; a fontanelle is present, however, on both sides. This form seems to be a transitional stage as the two sides are irregular, but how much of an individual variation may be seen in this is hard to say. In *fasciatus* there is a fontanelle, and in comparison with *skiltonianus* it is shortened, leaving a slight space of irregular shape between parietal, postorbital and postfrontal bones as if this bone had shortened, leaving merely a membrane in its place. In *longirostris* the median posterior border seems to be eroded, leaving a space or vacuity of greater extent than the two former species. In *Eumeces humilis* great shortening has been accomplished, but here, instead of a concave outline posteriorly, the limit is decidedly convex, the cavity is slight between the parietal and postorbital; more extensive than in *fasciatus* but less than in *Eumeces longirostris*. In *Eumeces schneiderii pavimentatus* the vacuity is the greatest of all forms studied, and the posterior extent of this bone is shortened, leaving a concave outline; accompanying this shortening, the parietal bone has become indented, allowing more space along its lateral border. This is the climax of retrogression in all forms studied.

The postorbitals are associated with the fontanelles and seem to show a dwindling in the series studied. This bone is connected directly in some skulls with the appearance of the fontanelle while in others the fontanelle is absent but the bone has dwindled. In *Eumeces chinensis* and *tetragrammus* the skull is solid and the bone is elongated, probably extending to its limit posteriorly. In *chinensis* this bone is located along the lateral border of the skull, as the jugal and squamosals are separated. Next is a series of skulls that seem to represent a degeneration or progressive shortening and dwindling of the bone when the fontanelle appears. The series is as follows: *Eumeces skiltonianus, fasciatus, humilis, longirostris, schneiderii*

pavimentatus. Two other species may be added as a continuance of this dwindling but without having a fontanelle. What may have become of it or whether these have ever had them is hard to determine as no evidence exists. In *laticeps* and *septentrionalis* this bone has continued dwindling. In the last-mentioned one it is only a small sliver between the postfrontal and jugal and squamosal bones.

The squamosal, because if its marginal connection with the posterior limits of the skull and its association with jugal and parietal, is of interest, but is not so variable as some of the other bones. In *tetragrammus* the anterior connection of the squamosal with the jugal is broad and firm and is about equal to the postorbital and postfrontal in size. In the following four species, *fasciatus, obsoletus, septentrionalis, humilis,* the squamosal connects with the jugal by a slight articulation. In *skiltonianus* and *laticeps* there is a slight separation and the postorbital intervenes between jugal and squamosal. In *longirostris* and *chinensis* there is a gap between the jugal and squamosal.

The supratemporal is a curved sliver-shaped bone located between squamosal, parietal, paroccipital and quadrate bones. In *chinensis* it seems as a mere sliver slightly separated from the postorbital bone, while in fasciatus on the right side it is definitely in contact with it. In *Eumeces septentrionalis* it is slim and continued anteriorly, but not in contact with the postorbital. In *laticeps* it is widely separated from the postorbital.

CONCLUSIONS.

The following conclusions may be drawn from the foregoing observations on the skulls of *Eumeces* of the *Scincidæ*.

Changes are taking place in the dorsal surface of the skull, *e. g.*:

(1) A vacuity or frontanelle appears between the parietal, squamosal and postfrontal bones.

(2) The postorbital is either greatly elongated and broad; or short and triangular; or sliver-shaped, elongated and narrowly pointed at each end.

(3) The jugal has probably been lost completely.

(4) The supratemporal is small and crowded between the squamosal and parietal bones.

(5) The squamosal forms the posterior lateral angle of the skull extending from the quadrate to the jugal.

(6) The interparietal region has a small bone that has been called

the interparietal for want of a better term. This may be the dermal supraoccipital, which is not recognized as occurring in the squamata.

(7) The supraocular lies along the anterior median surface of the orbit.

(8) The premaxillary teeth are three in number on the left side and four on the right (one exception 3-3, *vide supra*); the two bones are unequal in size.

(9) The pterygoid teeth and the maxillary teeth are quite variable.

(10) A small bony plate on the quadrate bone may be the remains of the quadrate-jugal.

(11) Small posterior toothlike processes are invariably present, suggestive of vomerine teeth.

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(3) COPE: Annual Report of Nat. Hist. Mus., 1898 (1900), pp. 624-665.

(4) CUVIER: Recherches sur les ossemens fossiles, 1825, Tom. V, part II; chap. II, pp. 251-299.

(5) SIEBENROCK: Annal. K. K. Naturh. Hofmuseums, Wien, 1892, VII, heft 3, pp. 163-195, pl. XI and XII.

(6) SIEBENROCK: Annal; K. K. Naturh. Hofmuseums, Wien, 1895, X, heft, 1, pp. 19-40; pl. III.

(7) WILLISTON: Osteology of the Reptiles. 1925, pp. 65-72.

EXPLANATION OF ABBREVIATIONS.

BAO	Basioccipital.	PARO	Paroccipital.
BSP	Basisphenoid.	PFR	Postfrontal.
COL	Columella.	PO	Postorbital.
EPG	Epipterygoid.	P. PA. V	Postpalatine vacuity.
EXO	Exoccipital.	PREMAX	Premaxillary.
FR	Frontal.	PRF	Prefrontal.
FV	Fontanelle-vacuity.	PREVOM	Prevomer.
INTP	Interparietal.	PRO	Proötic.
JU	Jugal.	PTG	Pterygoid.
LA	Lachrymal.	Q	Quadrate.
MAX	Maxillary.	SO	Supraoccipital.
NA	Nasal.	SQ	Squamosal.
PA	Parietal.	SUA	Supraoccular.
PAL	Palatine.	SUPT	Supratemporal.

EXPLANATION OF PLATES.

Note.—All specimens originally drawn × 10 and reduced.

PLATE XXI.

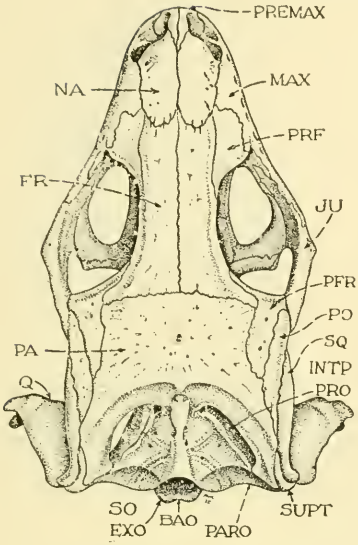
FIG. 1. *Eumeces chinensis* (Gray) Amoy, China. Adult male. E. H. Taylor, Private Coll. No. 880. S. F. Light. Coll. Skull dorsal view. (Quadrate disarticulated but reconstructed in place.)

FIG. 2. *Eumeces chinensis* (Gray) same specimen, ventral view.

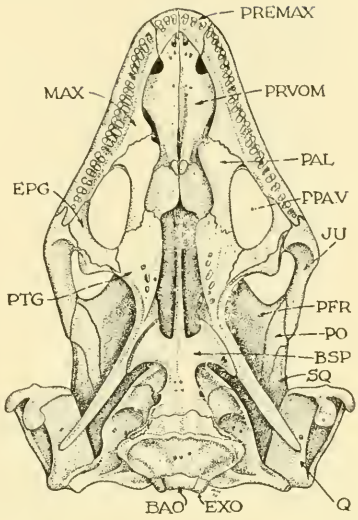
FIG. 3. *Eumeces obsoletus* (Baird and Girard). E. H. Taylor Coll. No. 881, Lawrence, Kan. E. H. Taylor, Coll. Skull, dorsal view.

FIG. 4. *Eumeces obsoletus* (Baird and Girard). Same specimen, ventral view.

PLATE XXI.



1. Eumeces chinensis.



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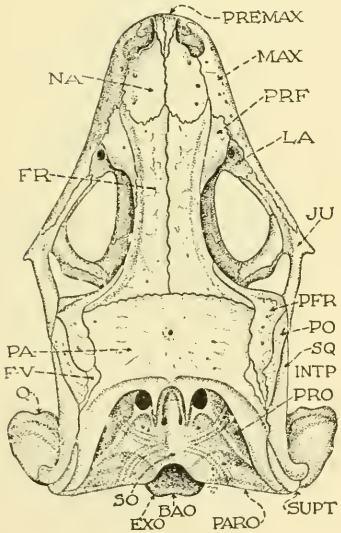
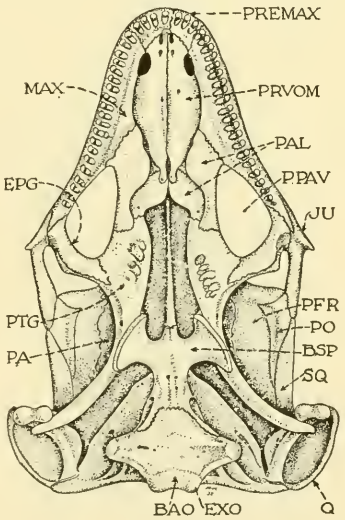


3. Eumeces obsoletus.



4. Eumeces obsoletus.

PLATE XXII.

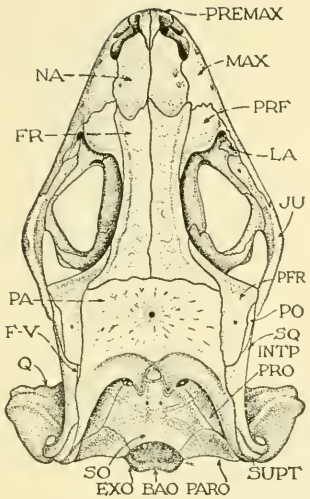
FIG. 1. *Eumeces laticeps* (Schneider). Kansas University Museum, No. 9127, Imboden, Ark. Byron Marshall, Coll. Adult female [here considered distinct from *fasciatus*]. Skull, dorsal view.

FIG. 2. *Eumeces laticeps* (Schneider). Same specimen, ventral view.

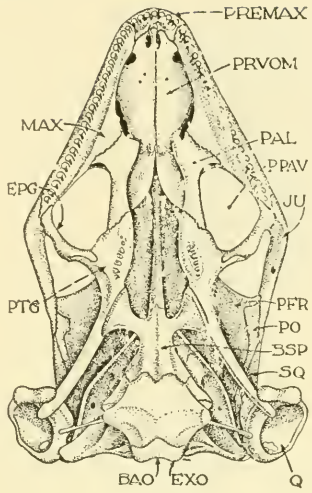
FIG. 3. *Eumeces schneiderii pavimentatus* (Geoffroy). Haiffa, Syria. No. 860, E. H. Taylor Coll. (Identified by Dr. R. Mertens.) Skull, dorsal view.

FIG. 4. *Eumeces schneiderii pavimentatus* (Geoffroy). Same specimen, ventral view.

PLATE XXII.



1. Eumeces laticeps



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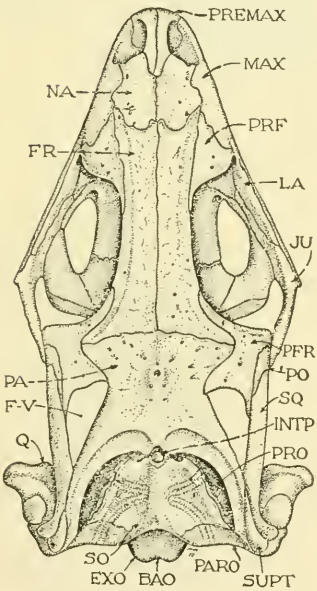
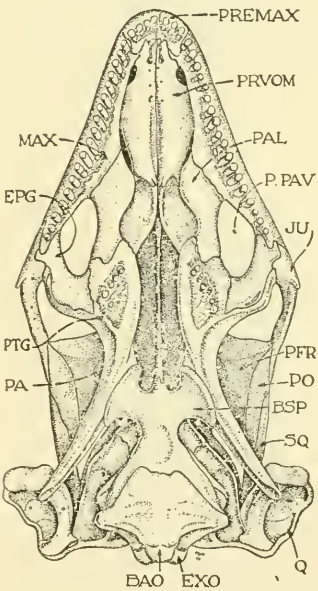


3. E. schneideri pavimentatus.



4. E schneideri pavimentatus.

PLATE XXIII.

FIG. 1. *Eumeces humilis* Boulenger? K. U. M. No. 7301, E. H. Taylor, Coll. (Not certainly identified). Skull, dorsal view.

FIG. 2. *Eumeces humilis* Boulenger. Same specimen, ventral view.

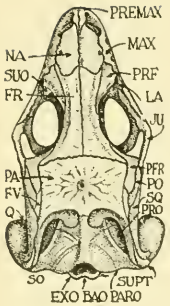
FIG. 3. *Eumeces tetragrammus* (Baird). E. H. Taylor, Private Coll., No. 804, Cameron county, Texas. E. H. Taylor, Coll. Skull, dorsal view. (Partly reconstructed, teeth figured but part missing.)

FIG. 4. *Eumeces tetragrammus* Baird. Same specimen, ventral view.

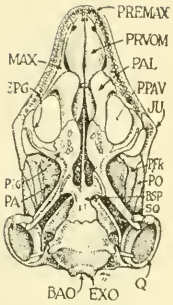
FIG. 5. *Eumeces septentrionalis* (Baird). K. U. M. No. 7361, Douglas county, Kansas. J. R. Jeffries, Coll. Skull, dorsal view.

FIG. 6. *Eumeces septentrionalis* (Baird). Same specimen, ventral view.

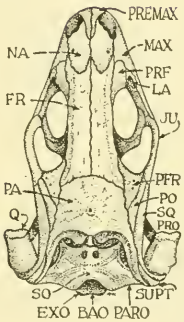
PLATE XXIII.



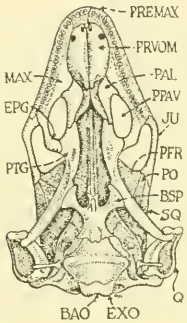
1. Eumeces humilis



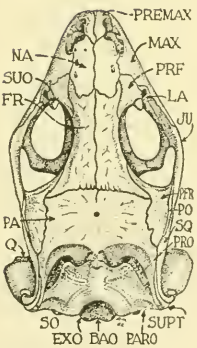
2. Eumeces humilis



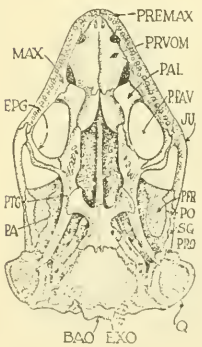
3. Eumeces tetragrammus.



4. Eumeces tetragrammus.



5. Eumeces septentrionalis



6. Eumeces septentrionalis

PLATE XXIV.

FIG. 1. *Eumeces skiltonianus* (Baird and Girard). (*Eumeces gilberti* Van Denburgh.) K. U. M. No. 8796, San Diego county, California. L. M. Klauber, Coll. Skull, dorsal view.

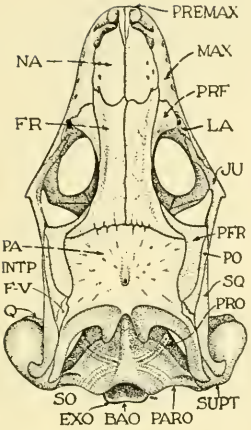
FIG. 2. *Eumeces skiltonianus* (Baird and Girard). Same specimen, ventral view.

FIG. 3. *Eumeces fasciatus* (Linnaeus). Douglas county, Kansas. R. H. Beamer, Coll. Skull, dorsal view.

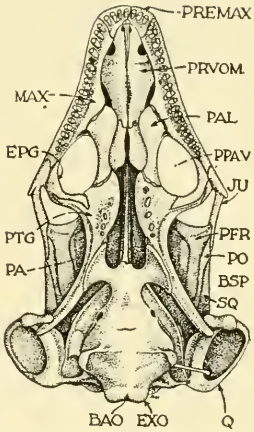
FIG. 4. *Eumeces longirostris* Cope. K. U. M. No. 8211. Bermuda, Castle Island. T. H. Bean, Coll. Skull, dorsal view.

FIG. 5. *Eumeces longirostris* Cope. Same specimen, ventral view.

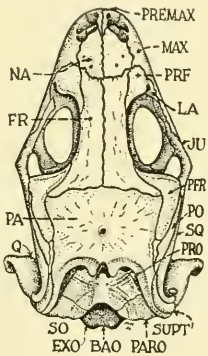
PLATE XXIV.



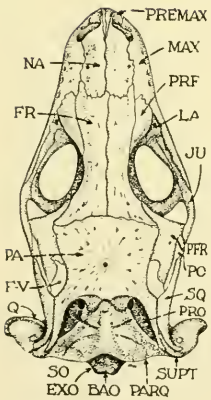
1 Eumeces skiltonianus



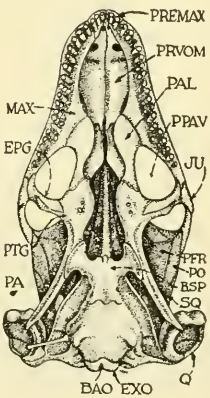
2. Eumeces skiltonianus.



3. Eumeces fasciatus



4 Eumeces longirostris.



5. Eumeces longirostris.

THE UNIVERSITY OF KANSAS
SCIENCE BULLETIN

VOL. XX] MAY, 1932 [No. 16

A Monograph of the Genus *Metrobates* (Hemiptera, Gerridæ).*

LAUREN D. ANDERSON, Lawrence, Kan.†

METROBATES is comprised of a group of very active water striders which cruise over the water by quick, jerky movements, using their long middle legs as oars. They are gregarious insects, appearing as large patches of black on the quiet lakes and calm, bayed-out parts of our inland streams. When disturbed they scatter in all directions with lightning speed.

They feed on small insects such as mosquitoes and flies, often jumping several inches into the air to catch their prey in flight. Only rarely are the macropterous forms found, and they have only been taken in the species *M. hesperius* Uhler. Parshley recorded an interesting find of a brood of winged forms July 22, 1926, at Cold Spring Harbor, taking several hundred macropterous specimens.

Metrobates are not uncommon, but decidedly local in occurrence, and therefore they are not found in abundance in insect collections. The writer observed large numbers of *M. trux* (Bueno) skating on the quiet waters of the Republican river at Morganville, Kan., in late September, 1931. This was during the migration season of wild ducks, and the crops of several wild mallard ducks, upon examination, revealed hundreds of this species of *Metrobates*.

The author attempted to establish a colony of *M. trux* (Bueno) in an aquarium. Specimens were carried home in a wet water net and placed in a tub of fresh well water. Their bodies and legs had be-

* Contribution from the Department of Entomology, University of Kansas.

† ACKNOWLEDGMENT.—The writer wishes to acknowledge herewith his indebtedness to those who have aided in his work; to Dr. H. B. Hungerford, under whose direction this study was made, and to Dr. R. H. Beamer, also of the University of Kansas, he feels greatly indebted for the very kindly advice and suggestions they have given and for their generosity in placing at his disposal material and equipment that made this work possible. Thanks are also due to Dr. C. H. Kennedy, of Ohio State University, for his helpful, kindly suggestions on arrangement of material in this paper; to Mrs. R. H. Beamer, whose interest and help in collecting some of the type material has been a great inspiration, and to J. O. Nottingham for his assistance and many kindly suggestions.

come wet from contact with the net and as a result they could not stay on the surface, but swam frantically aimlessly about under the surface and soon some individuals died. The living were removed from the water and allowed to remain in the direct sunlight in a dish pan until they were thoroughly dry, then replaced on the water and they were able to resume their normal swimming habit. The tub was left in an exposed position that night and a heavy dew fell. The next morning the majority of the specimens were under the surface dead or dying. A few that had climbed on a small board remained alive and normal. So few living specimens were left the experiment was discontinued.

Uhler reports for *M. hesperius* (Standard Nat. Hist. II, p. 271, 1884): "The eggs are attached during early summer to the projecting twigs, leaves and stems of water plants, and by the middle of the season multitudes of the young may be seen in company with the adults."

At present very little is known of the biology of this interesting group of water striders.

TAXONOMIC POSITION OF METROBATES.

Gerridæ and Veliidæ are separated from other families of Hemiptera by the presence of exposed antennæ, four segmented antennæ, and claws of at least the front tarsi distinctly anteapical, the apex of the last tarsal segment more or less cleft or bifid. Gerridæ and Veliidæ are separated as follows:

a. Hind femora much surpassing apex of abdomen; middle and hind coxæ approximate, distant from front ones.....GERRIDÆ

aa. Hind femora but little if at all surpassing tip of abdomen; middle coxæ (except *Rhagovelia*) equally distant from front and hind ones, VELIIDÆ

KEY TO GENERA OF GERRIDÆ IN NORTH AMERICA NORTH OF MEXICO.

1. Inner margins of the eyes sinuate or concave behind the middle. Body comparatively long and narrow.....Subfamily GERRINÆ 2
1. Inner margins of eyes convexly rounded. Body comparatively short and broad.....Subfamily HALOBATINÆ 3
2. (1) Pronotum sericeous, and fused with mesonotum, antennæ comparatively short and stout.....*Gerris*
2. (1) Pronotum glabrous, not fused with mesonotum, antennæ comparatively long and slender.....*Tenagogonus*
3. (1) First antennal segment as long as the other three united, hind femur twice length of hind tibia.....*Metrobates*
3. (1) First antennal not as long as the other three united, hind femur not twice length of hind tibia..... 4
4. (3) Fourth antennal equal to or shorter than third, hind femur equal to or shorter than hind tibia and tarsus united, abdomen as long as remainder of body.....*Rheumatobates*

4. (3) Fourth antennal longer than third, abdomen much shorter than remainder of body..... 5
5. (4) Black and yellow, eyes large and fairly prominent; lacustrine..... *Trepobates*
5. (4) Leaden-gray, eyes small and widely separated; oceanic....*Halobates*

METROBATES Uhler 1871.

TYPE: Proc. Bost. Soc. Nat. Hist., XIV, p. 108, 1871.
UHLER: Proc. Bost. Soc. Nat. Hist., XIX, p. 437, 1878.
KIRKALDY: Trans. Amer. Ent. Soc., XXXII, p. 155, 1906.
BUENO: Trans. Am. Ent. Soc., XXXVII, pp. 246-249, 1911.
ESAKI: Nat. Museum Hungaria, 1926.
HUNGERFORD: U. Kan. Sc. Bull. XI, p. 143, No. 17, 1919.

The following description of *Metrobates* Uhler is based on the apterous form, the macropterous form being rare.

SIZE. With genital segments: 3 to 5 mm. long, 1.5 to 2.7 mm. wide, and .75 to 1.25 mm. thick. The males slightly smaller than the females. Winged forms larger thorax due to presence of wings and wing muscles.

COLOR. Opaque, velvety, lead-gray, and black, with yellow and orange markings on the appendages, head and thorax. On the head there are two diverging orange spots on the posterior margin between the eyes. The pronotum has a slightly depressed orange or red area. Mesonotum with lead-gray and black irregular longitudinal stripes, the lead-gray stripes taking on a blue appearance in the darker forms. Specimens tend to change to black with age.

STRUCTURAL CHARACTERISTICS. Robust and broad.

Head: With eyes wider than prothorax. Antennæ stout, almost as long as the entire body, basal joint as long as the other three united (heavier on males than females), second and fourth joints subequal, third slightly shorter than second or fourth. Rostrum stout, hairy, extending beyond basal line of the prosternum.

Thorax: Pronotum small, subrectangular, slightly depressed in middle (in macropterous forms very large, being the largest division of the thorax, the posterior lobe long and forming a broad triangle), set in mesothorax, the mesothorax composing the largest division of the body, and is dorsomesially divided. Metanotum subrectangular. The prothoracic legs stout, far forward and fitted for grasping. Fore legs often have characteristic specific spines. Mesothoracic and metathoracic legs close together and distant from prothoracic legs. Intermediate femur about two-thirds length of posterior, intermediate tibia nearly as long as posterior femur and tibia conjoined, intermediate tarsus equal to posterior tibia and tarsus con-

joined. In macropterous form the hemelytra is longer than body, corium of two cells, nervures very prominent, membrane with a submarginal nervure.

Abdomen: Six segments, broad and short, connexivum prominent and erect, penultimate segment of female notched for reception of the genital segment. Male genital segment truncate, prominent, claspers sometimes visible, but usually withdrawn within basal genital segment. Female genital segment as viewed from above short and nearly hidden beneath the sixth tergum, as viewed from below basal segment triangular with anterior margin convex as showing out from under the concave posterior margin of the sixth venter. The second segment appears as a knob on the posterior apex of the first genital segment. Ovipositor and genital opening in median portion of basal segment.

DISTRIBUTION: *M. hesperius* Uhler: Ontario, New York, Maryland, North Carolina, Mississippi, Alabama, Florida, Tennessee, Louisiana, Arkansas, Kansas, Minnesota. *M. artus* Anderson: Texas. *M. trux* (Bueno): Idaho, Colorado, Kansas. *M. denticornis* (Champion): Mexico, and Guatemala, C. A. *M. tumidus* Anderson: Cuba and Jamaica. *M. porcus* Anderson: Rio Grande, British Honduras.

SYNONOMY OF METROBATES.

METROBATES Uhler 1871 *vs.* TREPOBATOPSIS Champ. 1898.

I have before me copies of the original descriptions of *Metrobates* Uhler 1871, and *Trepobatopsis* Champ. 1898. After careful comparison of the descriptions, both generic and specific, and also comparing specimens of each, I am convinced that there is not a generic difference between the two. So I am placing *Trepobatopsis* in synonomy, as *Metrobates* is the older name.

Specimens of *T. denticornis* Champion and *T. trux* Bueno will fit into Uhler's description of *Metrobates* with only minor differences, such as a very slight difference in length of the antennal segments and segments of the legs, and degree of dorsoventral thicknesses of the thorax (*Trepobatopsis* being the thinner). Winged specimens of *T. trux* Bueno and *T. denticornis* Champion are unknown at present.

Specimens of *M. hesperius* Uhler will fit into Champion's description of *Trepobatopsis* with only minor differences, such as a greater extension of the pleura forward towards the eyes in *Trepobatopsis* than in *Metrobates hesperius* Uhler, and a slightly longer genital segment in *Trepobatopsis* Champion. The tooth on the femur of *T. denticornis* Champion should not be used as a generic character

as it seems to be only a male character as Champion suggests, also *T. trux* Bueno does not have the tooth on the femur.

To further confirm the placing of *T. trux* Bueno and *T. denticornis* Champion in the genus *Metrobates,* and casting *Trepobatopsis* Champion into synonomy, I am describing three new species, *M. artus, M. tumidus* and *M. porcus,* that serve as very good intervening forms between *Metrobates* Uhler and *Trepobatopsis* Champion.

Lastly I place *Trepobatopsis* Champion in *Metrobates* Uhler because of similarity of the male claspers, a character I find very constant and of great value in specific determinations.

The following generic descriptions of *Metrobates* Uhler and *Trepobatopsis* Champion, are copies of the original descriptions that were used in the above comparison:

"*Metrobates* Uhler (Proc. of Bost. Soc. Nat. History. Vol. XIV, p. 108, 1871). Similar to *Halobates* Esch. (autor.). Robust and broad. Antennæ stout, almost as long as the entire body, the basal segment nearly as long as the three others united, curved at base, narrowing in that direction, much stouter in the male and expanded at the tip, the underside with erect hairs; second segment about one-third the length of the basal, greatly enlarged at tip, the third shortest, also enlarged at tip, fourth very stout, fusiform, almost as long as the second. Pronotum ample (in the unwinged form narrow and short, the mesothorax forming the stoutest and largest part of the body), a very little wider than long, the posterior lobe large, and extending back in the form of a broad triangle with the sides nearly straight and the tip a little rounded; the lateral margins, including the humeri, forming high, broad ridges. Anterior legs stout, the tibiæ a little curved at tip, with the process small and almost in continuous contact with the surface on which it stands; the basal joint of tarsi about one-fourth the length of the second, the second having the unguicule placed about one-third from the tip. Intermediate femora about two-thirds the length of the posterior, the tibia not quite as long as the posterior femur and tibia conjoined; the tarsus equal in length to the posterior tibia and tarsus conjoined. Corium of hemelytra short, with two elongate cells occupying nearly the whole width; membrane more than twice as long as the corium, the looped nervule running parallel to the entire margin."

"*Trepobatopsis* Champion (1898, Biol. C. Am., Hem. Het., II, p. 157). Head very broad, short, convex, produced and declivous in front, angularly dilated on each side above the insertion of the antennæ, broadly emarginate behind for the reception of the pronotum; the eyes finely faceted, large, oblique, and widely separated; rostrum short, reaching the front of the mesosternum; antennæ nearly as long as the body (exclusive of the genital segments), four segmented, one very elongate, curved at base, longer than the others united, two and three (male) furnished with dentiform processes at the apex beneath. Pronotum very short, much narrower than the head (with eyes), subtruncate in front and behind, rounded at the sides, and depressed in the middle; the propleura vertical, narrowing downwards, and not visible from above. Mesonotum trapezoidal, sinuate at the sides, and trisinuate behind, not distinctly separated laterally from the pleura; the latter very broad, rounded at the sides in front, extending forward as far as the eyes and back-

ward to beneath the metapleura. Metanotum with a deep oblique groove on each side; metapleura broad, extending backward to as far as the apex of the second dorsal abdominal segment. Abdomen very short, with moderately broad, flattened connexivum, the six segments united shorter than the mesonotum; first genital segment (male) very broad, parallel, as long as the three preceding segments united, covering two small terminal segments, which are not visible from above. Anterior coxæ narrowly separated, the antecoxal pieces received in the cavity beneath the eyes; anterior femora (male) slender, about one-third longer than tibia, armed with a stout tooth on the lower edge; anterior tibiæ armed with a strong curved tooth at the inner apical angle; anterior tarsi two segmented, about half the length of the tibia, joint one short, two about three times as long as one, with two claws inserted at about the middle beneath. Intermediate femora a little stouter than, and about two-thirds the length of, the tibiæ of the same pair of legs. Mesosternum separated from the mesopleura by a well-defined groove, which extends forward to beyond the middle. Body short, broad, depressed apterous.

"The remarkable insect from which the above characters are taken is perhaps nearest allied to *Trepobates* Uhler (= *Stephania,* Buch. White). The greatly developed mesonotum, with the broad pleura extending forwards as far as the eyes, gives it a peculiar facies. The armature of the second and third joint of the antennæ, and also that of the anterior femora, is probably a male character. The hind femora, as in *Trepobates* and *Metrobates* are very much longer than the intermediate femora. (In the unique examples seen the intermediate tibiæ and tarsi are broken off.) In Bianchi's arrangement of the Halobatini it would come near *Metrobates* Uhler, this genus having a similar elongate basal joint to the antennæ."

KEY TO SPECIES OF METROBATES.

1. Mesosternum divided by a median suture, prothorax margins angulate.. 2
1. Mesosternum not so divided, prothorax margins parallel. (Claspers Pl. XXV, Fig. 1) ..... *M. hesperius* Uhler
2. (1) Mesosternum male with prominent spines at base of legs and females with posterior margin of the sixth tergum three or more times telson. (Claspers Pl. XXV, Fig. 3)..... *M. porcus* Anderson
2. (1) Mesosternum male lacking spines, and posterior margin sixth tergum female same width as telson..... 3
3. (2) Front femur of male with prominent median spine on inner margin; females nearly same as females of *trux, trux* being heavier, and lighter. (Claspers Pl. XXV, Fig. 6)..... *M. denticornis* (Champ.)
3. (2) Front femur of male not so armed..... 4
4. (3) Second antennal segment black, body less than half as wide as long; dark in color, Cuban form. (Claspers Pl. XXV, Fig. 4) *M. tumidus* Anderson
4. (3) Second antennal yellow or partially yellow, body half as wide as long 5
5. (4) Second antennal with basal half yellow, spines on front tibia prominent, sharp; more flat than *artus* and larger. (Clasper Pl. XXV, Fig. 5)..... *M. trux* (Bueno)
5. (4) Second antennal all yellow but distal tip, spine on front tibia less prominent, blunt; more upright than *trux* and smaller. (Claspers Pl. XXV, Fig. 2)..... *M. artus* Anderson

Metrobates artus Anderson.

Anderson, L. D., Journal of Kansas Ento. Soc., vol. V, p. 56, 1932.

SIZE. With genital segments; male 3 mm. long and 1.1 mm. wide; female 3 mm. long and 1.8 mm. wide.

COLOR. Opaque, velvety, lead-gray, and black, with yellow and orange markings on the appendages, head and prothorax. First antennal segment amber at base with the rest black, second all amber except the tip, which is black, third and fourth black. On the head there are two diverging orange spots on the posterior margin between the eyes, and four distinct black spots in a line parallel to the inner margin of the eyes. The pronotum has a slightly depressed orange area in the center. The mesonotum with a gray median band, darker on either side, fading to gray laterally. Genital segments black.

STRUCTURAL CHARACTERISTICS. The fore tibia armed on the inner angle of the distal end with a prominent spine (a male character), and one to several long hairs. The relative average length of the antennal segments: Male: First, 25.7; second, 9.6; third, 5.8; fourth, 7. Female: First, 25; second, 9.8; third, 6; fourth, 7. Second and third antennal segments armed with a double fine-toothed comb at the distal end. Head (with eyes) robust, wider than prothorax. Pronotum subrectangular, flat, small and set in mesonotum. Mesothorax broad, lateroanterior margins projecting along sides of the pronotum, dorsomesially divided, dorsoposterior margin with a median V-shaped notch. Metanotum subrectangular, about twice as wide as long, with posterior margin slightly sinuate, and crossed by a median transverse, anteromesially curved sulcus. Abdomen without genital segments, one-half as long as the thorax, nearly as wide as long, bent downwards in middle, genital segment (male) truncate; female genital segment short, usually withdrawn in sixth abdominal.

Male claspers flat, about one-half mm. long, one-twelfth mm. at widest place, and has a restricted right angle bend two-thirds the distance back from the distal point; the distal two-thirds is lance-like, tapering to a sharp point. Clasper of *M. trux* (Bueno) and *M. denticornis* (Champion) are about the same length, but much wider and more swollen and have a very blunt point. Claspers of *M. hesperius* Uhler and *M. tumidus* Anderson are only half as long and are very plump, almost club like. Claspers of *M. porcus* Anderson shorter, broader, and with rounded point. See Plate XXV, Fig. 2.

Holotype, wingless male; allotype, wingless female; paratypes, wingless, 12 males, 20 females, Cameron county, Texas, Dr. R. H. Beamer, collector, Aug. 3, 1928; 1 male, 2 females, Kendall county, Texas, Dr. R. H. Beamer, collector, Aug. 7, 1928; 2 females, Brazoria county, Texas, Aug. 12, 1928; 1 female, Bowie county, Texas, Mrs. R. H. Beamer, collector, Aug. 16, 1928. Types in Snow Entomological Collection, University of Kansas, Lawrence, Kan.

NOTES. Arranging the species of *Metrobates* Uhler according to the dorsoventral thickness of the thorax, *M. trux* (Bueno), *M. denticornis* (Champion) and *M. porcus* Anderson would be dorsoventrally flattened and *M. hesperius* Uhler more upright, with *M. tumidus* Anderson and *M. artus* Anderson as the intervening steps, the latter being the thinner. *M. artus* is readily separated from the other five by having the second antennal segment amber color, absence of heavy spines on the fore femur or mesosternum, mesosternum with median suture, and a very characteristic male clasper.

Artus is a Latin adjective meaning narrow, which partly describes the form of the male claspers.

Metrobates denticornis (Champion) 1898.

Champion, Biol. C. Am., Hem.-Het., II, p. 158, 1898.
Drake & Harris, Ohio Jl. Sci. XXVIII, p. 273, 1928.

(Champion: Biol. C.-Am., Hem.-Het., II, p. 157, 1898.) "Male. Black, opaque; a broad sinuous stripe on the mesopleura, a stripe down the middle of the mesonotum, two spots on the metanotum, as well as on the sides, the middle and sides of the dorsum of the abdomen, and the metapleura, gray; the head with two oblique ferruginous spots at the base; the pronotum with rounded ochraceous spot in the center; the under surface bluish-gray, the apex of the abdomen and a spot on the antecoxal pieces of the mesopleura ferruginous or ochraceous; the first antennal joint at the base beneath, and the second joint to near the tip, ochraceous; above and beneath, the legs and antennæ clothed with short pubescence, the pubescence on the under surface whitish, the basal joint of the antennæ with a few long projecting hairs beneath. Antennæ not very slender, joint one about three and one-half times as long as two, two and four subequal in length, three shorter than two, four fusiform; joint two armed with two, and three with four, blunt, downwardly projecting teeth at the apex beneath. Anterior femora armed with a stout projecting tooth on the lower edge a little beyond the middle. Terminal ventral segment deeply arcuate-emarginate at the apex. Length 3½, breadth 2 mm. (millim.)
"Hab. Mexico (Salle, in Mus. Holm.)."

Drake and Hottes report this species from Texas, U. S. A. There are specimens of *M. denticornis* (Champion) in the Snow Entomological Collection, University of Kansas, Lawrence, from Guatemala, C. A. Determined by Champion. Claspers on Plate XXV, Fig. 6.

Metrobates hesperius Uhler 1871.

Uhler, Proc. Bost. Soc. Nat. Hist., XIV, p. 109, 1871.
Uhler, Proc. Bost. Soc. Nat. Hist., XIX, p. 437, 1878.
Uhler, Stand. Nat. Hist.., II, p. 271, 1884.
Van Duzee, Can. Ent., XXI, p. 6, 1889.
Bueno, Jl. N. Y. Ent. Soc., XIII, p. 41, 1905.
Bueno, Can. Ent., XLIII, p. 226, 1911.
Parshley, Psyche, XXI, p. 144, 1914.
Parshley, Brooklyn Ent. Soc. XXIV, No. 3, June, 1929.
Bianchi, Ann. Petersburg, 1896, p. 71.
Bueno (*Halobatopsis beginii Ash*) Can. Ent. XXIX, p. 56, 1897.
Hungerford, U. Kan. Sci. Bull. XI, p. 143, No. 17, 1919.
Blatchley, Heteroptera of N. America (Eastern).

(Proc. of Bost. Soc. Nat. Hist., Vol. XIV, 1871, p. 109.) "Opaque, velvety blue or brown-black, densely pubescent. Head robust, convex, brown at base and each side of it rufous or orange, minutely, densely pubescent, the face blackish. Rostrum black, beneath shining, above densely grayish pubescent, at base more or less orange. Antennæ black, pubescent, the basal one-fourth of the basal joint orange. Pronotum very small in the unwinged specimens, and less than one-half as long as wide, having the anterior margin a little concave, the surface finely, closely pubescent, the middle line broadly depressed, yellow, invaded by gray or whitish lead color, which expands in running back and covers the whole width of the tergum to its tip, omitting only a few black streaks on the disks and margins of the segments. The whole pectus, venter and two spots on the pleura lead color with a sericeous gloss.

"The winged form has the pronotum blackish brown, densely pubescent, the middle of the anterior lobe broadly depressed, covered by an orange spot, but lacking the bluish stripe. Coxæ yellow beneath, legs brownish-black, the anterior pair yellow at base, the yellow color continued further on the under side. Sternum blackish, each side of it yellowish. Hemelytra dark brown, with a faint, paler streak on the median suture, at base and on the costal margin pubescent. Venter cinereous, the disk of the penultimate and base of the last segment yellow.

"Length to tip of hemelytra 5 millims. Extreme width of mesothorax 2 millims. Mesothoracic width 1¾ to 2¼ millims. No. 29. Harris Collection."

DISTRIBUTION: New York, Maryland, North Carolina, Mississippi, Alabama, Florida, Tennessee, Louisiana, Arkansas, Kansas, Minnesota. Two immature specimens from Indio, Cal., that are probably *M. hesperius* Uhler, are in the Kansas U. Ent. Museum.

Claspers of male on Plate XXV, Fig. 1.

Metrobates trux (Bueno).

Bueno, Ent. News, 32, p. 274, 1921.
Hungerford & Moore, K. U. Sci. Bull., XIV, p. 420.

(Bueno: Ent. News, 32, p. 274, 1921.) "HEAD: Broader (including eyes), and longer than prothorax; tumid and as long as broad between the eyes. Eyes moderately large, quite oblique, shorter axis (breadth), four-fifths of the longer. Three large black shining setigerous loci in a line near each eye.

Antennæ slender (first two joints only present in type); basal joint curved at base; second joint one-fourth length of first, slightly enlarged at tip. Rostrum short, stout, three visible joints covered with long silvery gray hairs.

"THORAX: All three thoracic segments distinct dorsally. Pronotum about three times as wide as long, narrower than head with eyes, set in deep emargination in mesonotum. Prosternum with deep acetabula under eyes for anterior coxæ. Mesonotum twice as wide as long, divided medially by a deep longitudinal linear suture; anteriorly deeply rounded emarginate to receive the pronotum; posteriorly sinuate. Mesopleuræ extended backward to level of posterior margin of metanotum, simple, without sutures. Mesosternum simple, a deep submarginal suture dividing off the pleuræ for about one-half their length. Metanotum about one-half length of pronotum, sinuate posteriorly and divided in two by a sinuate cross suture; anterior part longer than posterior; lateral pieces (acetabula) for the coxæ running back half way of the second abdominal segment. Metasternum concealed.

"ABDOMEN: Slightly longer, including genital segment, than wide. Male; not quite as long (including genital segments) as wide. Female; connexivum wide, so reflexed as to be practically vertical; six abdominal segments visible dorsally and seven sternally, exclusive of the genital segment; sixth abdominal segment male beneath emarginate, trapezoidally posteriorly to receive the seventh segment; seventh segment twice as long as any of the others, roundedly emarginate to receive cylindrical genital segment; all other segments short and ringlike and subequal in length. Genital segment male cylindrical, rounded terminally, slightly longer than broad, as long as the four terminal abdominal segments taken together; beneath with a rounded operculum through which the genitalia show as two rounded protuberances, one in front of the other. Seventh abdominal segment female long and broad, beneath emarginate trapezoidally posteriorly to receive genital segment; all other segments short and ringlike and subequal in length. Genital segment female narrow, roundedly triangular with a keellike longitudinal slit and a knoblike apex.

"LEGS: Anterior femora moderately stout, unarmed, tibiæ one-quarter longer, more slender. Intermediate femora to tibiæ as seven to nine in length, slightly stouter than tibiæ, covered with stout hairs, spinelike in middle of leg, longer spinous bristles at ends of points. Two stout spines at distal end of femur. Anterior femora only present in type; other joints of legs described from the type series specimens.

"COLOR: Head somewhat flavous or darker with blackish pattern, covered with long silvery gray pubescence, the six setigerous loci shining black. Prothorax black, middle flavous and anterior margins broadly slate gray. Mesothorax black, a broad slate-gray stripe, and pleura and sterna all slate-gray; a double line of black spots running down the tergum, rather linear on the posterior margin of abdominal segments; male genital segment, the extreme knob of which is piceous. Abdomen beneath the same color, except that the black margins are more linear and placed on the posterior margin of each segment, widest on the sixth and disappearing on the first and second; the last (seventh) segment is broadly roundedly black in male and subtriangularly black medially in female. Edges of genital segment black in female, black in male.

"The general ground color is black, body pubescence silvery gray and long particularly on the rostrum, or slaty gray and velvety.

"DIMENSIONS: Type—long 4.4 mm.; lat., 2.2 mm. Allotype—long 5 mm.; lat., 2.7 mm.

"TYPE: Apterous male, Yampa river, Northwest Colorado, Aug. 20, 1920. Allotype, same data. Paratypes, 2 males and 5 females, same data. R. C. Moore, collector. Type, allotype, 1 male and 4 females, paratypes, in Snow Entomological Collection, University of Kansas; 1 male and 1 female, paratype, in Bueno collection.

"This species differs generically from *Trepobates* Uhler in the size and proportion of head; proportion of first two antennal joints, pronotal proportions, and structure of abdomen. The color and the proportions of the leg segments and the absence of teeth on the anterior femora and the intermediate tibia at once separate it from *Trepobatopsis denticornis* Champion."

Ninety-four females and 109 males, collected by the author, September, 1931, on the Republican river, Morganville, Kan., and one female from Idaho, collected by C. J. Drake, 1926, have been added to the Kansas U. Ent. Museum.

Male claspers of *M. trux* (Bueno) Plate XXV, Fig. 5.

Metrobates tumidus Anderson.

Anderson, L. D., Journal of Kansas Ento. Soc., vol. V, p. 56, 1932.

SIZE: With genital segments; male, 4 mm. long and 1.4 mm. wide; female, 4 mm. long and 1.9 mm. wide.

COLOR: Opaque, velvety, lead-gray, and black, with yellow and orange markings on the appendages, head and prothorax. First antennal segments amber at base with the rest dark, second, third and fourth dark. Head with two diverging orange spots on the posterior margin between the eyes, otherwise black. Pronotum with slightly depressed orange area in the center. Mesonotum with gray median band, darker on either side fading to gray at the lateral margins. Abdominal segments lead-gray with dark margins. Genital segments dark.

STRUCTURAL CHARACTERISTICS: The fore tibia armed on the inner angle of the distal end with a prominent spine (a male character) and one to several long hairs. The relative average length of the antennal segments: Male: First, 24; second, 7.4; third, 5; fourth, 7. Female: First, 23; second, 7; third, 5; fourth, 7. Second and third antennal segments armed with a double fine-toothed comb at the distal end. Head (with eyes) robust, wider than prothorax. Pronotum subrectangular, flat, small and set in mesonotum. Mesothorax broad, lateroanterior margins projecting along sides of the pronotum (not so noticeable as in *artus, denticornis, porcus,* and *trux*), dorsomesially divided, dorsoposterior margin with a median V-

shaped notch. Metanotum, subrectangular, about twice as wide as long, with posterior margin slightly sinuate, and crossed by a median transverse, anteriomesially curved sulcus. Abdomen, without genital segment, one-half as long as the thorax, nearly as wide as long, bent downward in middle. Genital segment male truncate; female genital segment short, not withdrawn in sixth abdominal.

Male claspers are the best character in distinguishing this species. The claspers are the smallest of the claspers found in the genus *Metrobates* Uhler. They are less than one-fourth of a millimeter long; the distal portion is flat and disklike, attached to the main body by a relatively slender stalk. Differs from *M. artus* Anderson, *M. denticornis* (Champion), *M. trux* (Bueno), and *M. porcus* Anderson by the greater length and size of these species; and differs from *M. hesperius* Uhler in that it is some smaller, and does not have the incurved margins that *M. hesperius* possesses. Plate XXV, figure 4.

Holotype, wingless male; allotype, wingless female, one paratype, wingless male, Spanish Town, St. Cathrine, Jamaica, March, 1899. Paratypes wingless, one male and three females from Mina Carlota, Trinidad Mountains, Cuba, March 22, 1925, collected by J. G. Myers. Types in Snow Entomological Collection, University of Kansas, Lawrence, Kan.

NOTES. Arranging the species of Metrobates according to the dorsoventral thickness of the thorax, *M. porcus* Anderson, *M. trux* (Bueno), and *M. denticornis* (Champion) would be dorsoventrally flattened and *M. hesperius* Uhler more upright, with *M. artus* Anderson and *M. tumidus* Anderson as the intervening steps, the latter being the nearer to *M. hesperius*, *M. tumidus* is readily separated from the other five by having such a characteristic clasper, and form of mesothorax, and slightly longer length of body, and narrower, and darker color.

Tumidus is a Latin adjective meaning swollen, which partly describes the form of the male claspers.

Metrobates porcus Anderson.

Anderson, L. D., Journal of Kansas Ento. Soc., vol. V, p. 56, 1932.

SIZE: With genital segment; male 3.8 mm. long, 2 mm. wide, and .75 mm. thick; female 4 mm. long, 2.4 mm. wide, and .80 mm. thick.

COLOR: Opaque, velvety, lead gray, and black, with yellow and orange markings on the appendages, head and thorax. First antennal segment amber at base, with the rest black, second with basal half amber, third and fourth all black. Head black with two diverg-

ing eliptical orange spots on the dorsal posterior margin between the eyes. The darker forms have a slightly depressed orange area in the center of the pronotum. Mesonotum with four longitudinal irregular black bands interspaced by three lead-gray bands. Genital segment dark. Abdomen lead gray with posterior margin of each segment black.

STRUCTURAL CHARACTERISTICS: The males have two very characteristic prominent downward projecting, yellow dark-tipped spines on the mesosternum at the base of each coxa; a character not found in any of the other species described in this paper. The fore tibia armed on the inner angle of the distal end with a prominent spine (a male character), and one to several long hairs. The relative average length of the antennal segments: Male: First, 24.5; second, 7; third, 5.2; fourth, 7. Female the same. Second and third antennal segments armed with a double fine-toothed comb at the distal end. Head (with eyes) robust, wider than prothorax. Pronotum subrectangular, flat, small and set in mesonotum. Mesothorax broad, lateroanterior margins projecting along the sides of the pronotum practically touching posterior margins of the compound eyes, dorsomesially divided, dorsoposterior margin with a median V-shaped notch. Metanotum subrectangular, almost twice as wide as long, with posterior margin slightly sinuate and crossed by a median transverse, anteriomesially curved sulcus. Abdomen, without genital segment one-half as long as thorax, nearly as wide as long, normally flat, genital segment (male) truncate; female genital segment short, usually nearly withdrawn under sixth abdominal tergum. Posterior margin of the sixth tergum (female) three or more times width of genital segments (not true with females of other known species).

Male claspers flat, about .4 mm. long, .1 mm. at widest place, have a rounded right angle bend two-thirds the distance back from the distal point, the distal two-thirds is lancelike, not coming to the acute sharp point as in *M. artus* Anderson. In size the claspers are between *M. hesperius* Uhler, and *M. artus* Anderson. The outer portion of the right-angle bend is nearly a perfect arc. *M. trux* (Bueno) and *M. denticornis* (Champion) have much heavier broader claspers and *M. tumidus* Anderson smaller and more plump. For claspers see Plate XXV, figure 3.

Holotype, wingless male; allotype, wingless female; paratypes, wingless, thirty-two males and twenty-three females, and ten nymphs. From Rio Grande, British Honduras, B. W. I., November,

1931, by J. J. White. Types deposited in the Snow Entomological Museum, University of Kansas, Lawrence, Kan.

NOTES: Arranging the species of *Metrobates* Uhler according to the dorsoventral thickness of the thorax, from the flatter to the thicker, *M. porcus* Anderson, *M. denticornis* (Champion), *M. trux* (Bueno), (the last two practically the same), *M. tumidus* Anderson, *M. artus* Anderson, and *M. hesperius* Uhler. *M. porcus* is readily separated from the other five species by the presence of the mesothoracic spines and claspers of the male, and shape of the sixth tergum of the female.

The name *porcus* suggested by the present economic depression.

PLATE XXV.

Male Genital Claspers of Metrobates

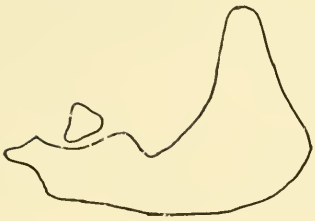


FIG 1 M. hesperius Uhler
Slide No 1

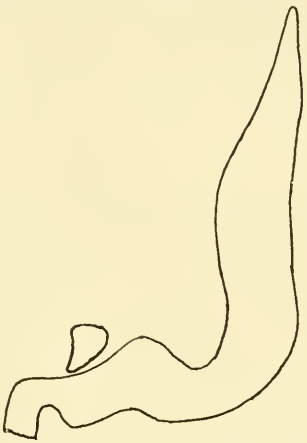


FIG 2 M. artus n sp
Slide No. 2

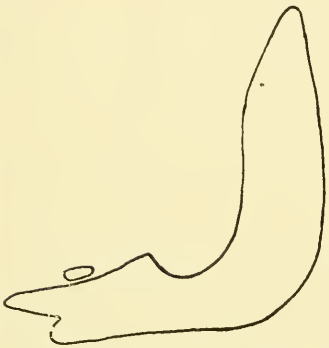


FIG 3 M. porcus n.sp
Slide No. 26

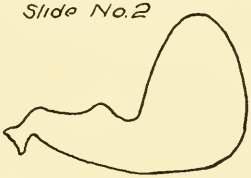


FIG 4 M. tumidus n sp
Slide No. 14

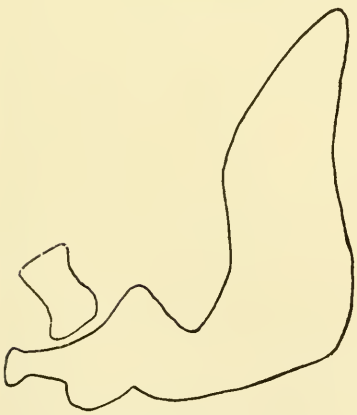


FIG 5 M. trux (Bueno)
Slide No 7

FIG. 6 M. denticornis (Champ)
Slide No. 8

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A New Stegocephalian from the Pennsylvanian of Arkansas.

H. H. LANE,

Kansas University Museum of Vertebrate Paleontology.

THE remains of stegocephalians from deposits of Pennsylvanian age are rare enough and of sufficient interest and importance to warrant the record of even fragmentary specimens, especially if, as in this case, they come from a new locality. The specimen in hand, a femur, was found in a chunk of semianthracite coal from the Eureka mine, located about one mile west of Paris, Ark. The Eureka mine is working a vein of semianthracite coal, 18 to 26 inches in thickness, embedded in the Paris shale, a deposit with a total thickness of about 600 feet. The coal itself lies in the form of a saucer, the edges of which outcrop nearly all around the margin of the field and inclose an area of perhaps three or four square miles. The Eureka mine is located near the center and bottom of the "saucer," so that this stegocephalian femur came from near the deepest part of the coal bed. The Paris shale is an important member of the Alleghany formation in the region of Paris, Ark., and its age is Upper (but not uppermost) Pennsylvanian. It overlies the Fort Smith formation.

The four chief sources of amphibian remains previously known from the North American coal measures are all, as Moodie has pointed out, in the Alleghany. These are (1) the South Joggins coal mines in Nova Scotia, where Sir William Dawson secured the microsaurs described by him; (2) the Linton, Ohio, coal deposits, whence Newberry and others obtained the material described by Cope; (3) the Mazon Creek, Ill., shales, the species from which were described by Newberry, Cope and Moodie; and (4) the Cannelton, Pa., slates from which Moodie described the material now in the United States National Museum. These localities are all east of the Mississippi

and north of the Ohio rivers. There is additional interest, therefore, in the discovery of these remains in the Alleghany of Arkansas.

The writer made a special visit to the Eureka mine, and, while accorded every courtesy and facility by the mine operatives, failed to find any further traces of vertebrate remains. There are invertebrate and vegetable remains in the shale below the coal bed, but no evidence of vertebrates could be found. Since the bone described below came from the coal itself, the only possibility of further discovery of such specimens lies in the difficult and tedious inspection of the "chunks" of coal as they come from the mine. The miners themselves, naturally enough, in the course of their activities had never observed vertebrate remains.

Despite the relatively large number (nearly ninety species) of carboniferous amphibians listed by Moodie, our knowledge of the group at that time is still "woefully incomplete," as "is attested by the fact that nearly every specimen collected represents a type distinct from any hitherto known," as Moodie has noted.

The specimen in hand probably belonged to some embolomerous stegocephalian, and is therefore of additional interest since almost nothing is known of the appendages in that group. In length and size it indicates an animal larger than most of the carboniferous forms known to the writer, and may have been about the size of *Archegosaurus, i. e.,* about 1.5 meters. Both in size and shape this femur is somewhat suggestive of that of *Aspidosaurus** figured by Williston from the Permian of Texas, a *rhachitimous* stegoceph from the Craddock Bone bed of Baylor county. Our specimen is, however, more likely an *embolomerous* form (since the Upper Carboniferous temnospondyls heretofore known belong to that subdivision), although in the absence of associated vertebræ this fact cannot be definitely established.

This new specimen (Pl. XXVI) has a length of 60 mm. to the point where the proximal end is broken off. Its greatest width across its distal enlargement is 19 mm. The shaft, which is much more slender than the ends, is decidedly triangular in cross section, and its outer surface is elevated into a fairly sharp ridge. This ridge (Fig. A), evidently the adductor crest, is relatively high and runs directly distad over the outer surface of the femoral shaft, rising rather gradually to its greatest height on or near the proximal end, or head, of the bone. The mesial surface of the shaft describes a gentle arc, *i. e.,* this femur is decidedly bowed or arched (Fig. B).

* Williston, S. W., American Permian Vertebrates, Plate XXXII, figure 4.

Since this specimen represents an entirely new form, it seems best to assign it to a new genus and species, despite its fragmentary character. I therefore designate it as—

Arkanserpeton arcuatum, genus et species nov.

TYPE: An imperfect femur of an embolomerous stegocephalian in the Museum of Vertebrate Paleontology, University of Kansas; catalogue number 1430; from the Eureka mine, near Paris, Ark., U. S. A.

HORIZON: A bed of semianthracite coal within the Paris shale, Alleghany formation, Upper Pennsylvanian.

DIAGNOSIS: Femur somewhat more than 60 mm. in length; distal end enlarged, with a width of about 19 mm., more or less; shaft curved and decidedly triangular in cross section, with a distinct, rather prominent adductor crest running directly distad along the convex outer side and rising gradually to its greatest height on or near the head of the femur. Mesial surface of the femoral shaft decidedly concave.

EXPLANATION OF PLATE XXVI.

FEMUR OF *Arkanserpeton arcuatum;* approx. nat. size.

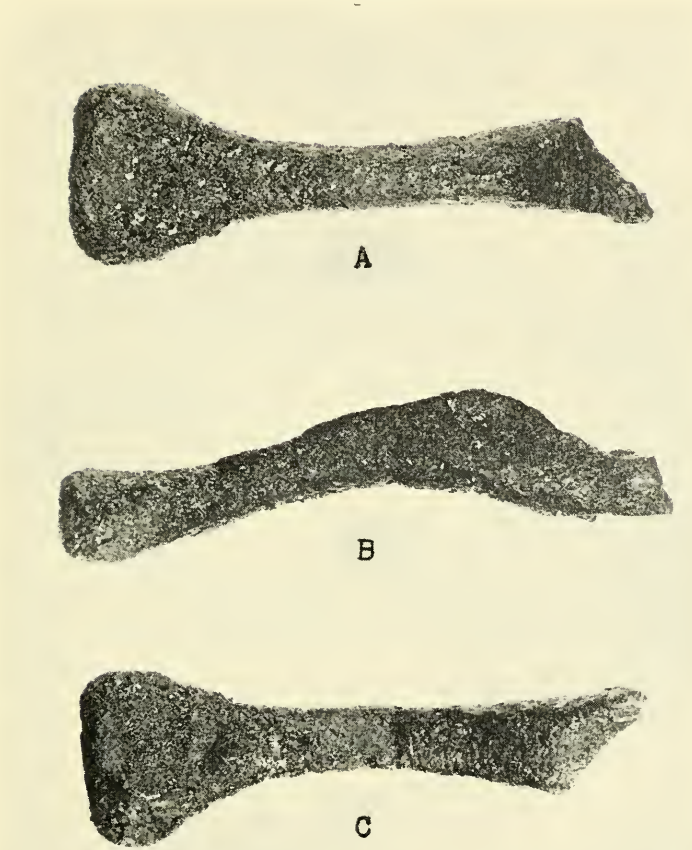
A. Outer surface of femur.

B. Anterior surface of femur.

C. Mesial surface of femur.

NOTE.—The apparent slight difference in the length of this femur as shown on the three photographs is due to the photographer's inaccuracy in measurement. They should all three be 60 mm. long.

PLATE XXVI.



THE UNIVERSITY OF KANSAS
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Variation in *Palæosyops*.

H. H. LANE,

University of Kansas Museum of Vertebrate Paleontology.

OSBORN'S long-awaited monograph on the titanotheres * records the evolutionary history of this group of mammals along five distinct lines of descent and makes clearly evident the author's conclusion that—

"No characters in any genus or phylum are stationary. During the long intervals of geologic time the members of each of these branches were constantly diverging in some characters and converging in others, and becoming more and more unlike one another both as a whole and, so far as we can observe, in each one of their single characters."

A careful examination of the data presented by Osborn, reinforced by the study of titanothere material collected by the writer in the Bridger deposits (Middle Eocene) of southwestern Wyoming, shows very clearly that the same fluidity of characters is observable within the limits of a species no less than in the genera and phyla to which Osborn restricts his discussion.

The accompanying table (Table I) arranged from data given by Osborn with the addition of data from a practically complete *Palæosyops* skull (University of Kansas, Museum of Vertebrate Paleontology, No. 4321) collected by the writer from horizon C^5—D^4 about a mile northeast of Cedar Creek Mountain, well illustrates this conclusion. All the specimens considered in this table are from Horizons C and D of the Bridger formation and with the exception of the University of Kansas skull are ascribed by Osborn to *Palæosyops leidyi* or *Palæosyops robustus*.

The type locality and geological horizon of *P. leidyi* is—

"Henry's Fork, Bridger Basin, Wyoming: Bridger formation, *Uintatherium-Manteoceras-Mesatirhinus* zone. Bridger levels C^2, C^3, C^4 and C^5?, as exposed on Henry's Fork in the Bridger Basin, are the geologic levels of this species, which is well above that of *P. major*—approximately 200 feet."

* Osborn, H. F.: The Titanotheres of Ancient Wyoming, Dakota and Nebraska. Monograph 55, U. S. Geol. Surv., vols. I and II, 1929, Washington, D. C.

TABLE I.—Variations in certain specimens of *Palæosyops* species.

Species	*Palæosyops leidyi.*					?	*Palæosyops robustus.*				
Museum catalogue number	Amer. Mus. 12185	Princ. Univ. 10009	Amer. Mus. 12196	Amer. Mus. 1516	Amer. Mus. 1544	Kan. Univ. 4321	Amer. Mus. 11678	Amer. Mus. 5106	Princ. Univ. 10282	Yale Univ. 11122	Amer. Mus. 11683
Bridger formation	C3	C?	C2	(C?)	C4?	C5-D4	D4	D?	D	?D?	D
Basilar length	.....	.....	.....	414	415	446	.....	.....	.....	*e*440	.....
Zygomatic breadth	.....	.....	.....	*e*275	310	323	*e*341	.....	.....	*e*340	.....
Occiput to nasal tips	.....	.....	.....	405	397	426	.....	.....	.....	.....	.....
Height of occiput	.....	.....	.....	.....	112	71	.....	.....	.....	.....	.....
Width across postglenoid processes	.....	.....	.....	188	196	251	.....	.....	.....	.....	.....
Premolar^1 to molar^3	162	.....	.....	169	174	165	.....	*e*170	174	*e*180	.....
Premolar^2 to molar^3	150	*e*150	.....	155	158	152	.....	.....	163	*e*170	169
Premolar^2 to molar^2	115	.....	.....	119	120	115	.....	.....	127	.....	131
Premolar^1 to premolar^4	.....	.....	.....	.....	73	68	.....	.....	.....	70	.....
Molar^1 to molar^3	98	97	96	102	100	98	94	*e*102	100	102	*e*103
Premolar^4—anteroposterior dimension	18	19	18	18	19	19	17	19	20	20	20
Premolar^4—transverse dimension	24	25	26	25	25	24	24	26	27	27	26
Molar^1—anteroposterior dimension	.....	29	29	29	29	27	27	.....	.....	29	30
Molar^1—transverse dimension	31	*e*31	32	34	33	27	31	.....	.....	35	35
Molar^3—anteroposterior dimension	34	35	32	34	36	37	33	.....	36	37	37
Molar^3—transverse dimension	39	39	41	39	38	38	37	42	40	42	42
Molar^3—oblique	48	48	48	48	48	48	52	.....	52	52	52
Cephalic index	.....	.....	.....	.664	.747	.724	.....	.....	.....	.773	.....

e, estimated. All dimensions are given in millimeters.

Since the University of Kansas No. 4321 was collected from level C^5—D^4, it possibly falls within the upper limits of the distributional range of *P. leidyi*, although it was found not on Henry's Fork, but a few miles northwest of that locality, a mile or so northeast of Cedar Creek Mountain. On the basis of Matthew's criteria for paleontological species, therefore, it should be compared very carefully and in detail with *P. leidyi*.

The five skulls of *P. leidyi* which Osborn had in hand constitute an evolutionary series, as he takes pains to point out. His first stage, represented by the American Museum of Natural History No. 12185, from level Bridger C^3, mouth of Summer's Dry Creek, is the most primitive. Comparing this specimen with the University of Kansas No. 4321, it may be noted that in both the second upper premolar is comparatively primitive. The total length of the premolar-molar series is 3 mm. longer in the latter than in the former—an insignificant difference. The sagittal crest at its narrowest point is slightly wider in the University of Kansas No. 4321, *i. e.*, 21 mm., than in the American Museum No. 12185, where it is only 17 mm. In both specimens the zygomata are robust. The protoconules, greatly reduced in No. 12185, are practically absent in No. 4321, except on the last upper premolar and the first and second upper molars, *not lophoid* as in No. 12185, but rather sharply conical. The canine in No. 4321 is decidedly longer than in No. 12185, measuring 40 mm. in height on its mesial face and 48 mm. on its external face, as compared with 36 mm. in No. 12185. Across the base of the crown it is also larger, 23 mm., as compared with 20 mm. in No. 12185. The molar crescents in both are of wide-angle type. In short, the University of Kansas specimen represents a larger individual—probably a male—and is slightly more progressive in its dentition.

Osborn's second evolutionary stage is represented by specimen No. 10009 from the Museum of Princeton University. Both the Princeton and the University of Kansas specimens have a very distinct mesostyle on the fourth upper premolar, a progressive feature. The University of Kansas No. 4321 shows an advance over the Princeton No. 10009, however, in having also a well-developed mesostyle on the third upper premolar, whereas in the latter this mesostyle is only rudimentary. The dimension of the second premolar-third molar series in the upper jaw is practically the same in both specimens—150 mm. in No. 10009 and 152 mm. in No. 4321. As in the Princeton specimen, the University of Kansas skull has

very distinct protoconules on all the upper molars, but unlike the former, in which the superior molars are without metaconules, No. 4321 has *well-developed* metaconules on the first and third upper molars, and a rudimentary but yet distinct one on the second molar. In this respect No. 4321 is distinctly more progressive than Osborn's second stage, as exemplified by Princeton No. 10009.

Osborn's third evolutionary stage is represented by the American Museum No. 1516, which has smooth horn-swellings *behind* the nasofrontal suture—a feature totally lacking in No. 4321. Whereas the former specimen has a moderate expansion of the zygomata—*i. e.*, 275 mm.—No. 4321 has a relatively enormous expansion of 323 mm. There is no apparent crushing in the latter skull to account for this difference, hence it is probably very significant. Still another marked difference is seen in the minimal width of the sagittal crest—only 13 mm. in No. 1516, or 4 mm. less than in stage 1, represented by No. 12185—while in the University of Kansas No. 4321 the minimal width of the sagittal crest is 21 mm.—a difference of 50 per cent, certainly sufficient to be significant, and apparently in No. 4321 indicates a *progressive* difference. The basilar length in the American Museum No. 1516 is given by Osborn as 415 mm. The same dimension in the University of Kansas No. 4321 is 446 mm., a difference of 31 mm.—another progressive modification. In No. 1516 the supratemporal crests are *very prominent, sharply* overhanging the temporal fossæ and terminating in prominent postorbital processes; while in No. 4321, the supratemporal crests are only *fairly prominent* and *only slightly* overhang the temporal fossæ. The convexity of the skull is broad *between* the orbits in No. 1516, while in No. 4321 the broad convexity of the skull is *distinctly posterior* to the orbits—a progressive feature. In No. 1516 the nasals have an extreme length of 175 mm.; in No. 4321, this dimension is 190 mm.—another progressive feature. With regard to the other characters of No. 1516 as given by Osborn, No. 4321 is in substantial agreement. For example, in both there is a posterolateral flange of the nasals beneath the maxillaries, lacrimals and frontals. In neither specimen is this flange largely covered by a forward extension of the frontals, but in side view it constitutes a V-shaped area between the frontals and the maxillaries. In both cases the maxillaries arch over the narial notch. This however, is to be expected since it is a generic characteristic of *Palæosyops*. In both the nasals diminish toward the tips in width and depth of decurvature, and in both the maxillaries enter broadly below the anterior part of the zygomatic arch.

Osborn's fourth evolutionary stage is represented by the type specimen of *Palæosyops leidyi*, viz., American Museum of Natural History No. 1544. This has very slight frontonasal horn-swellings, whereas the University of Kansas No. 4321 has none at all. The supratemporal crest in the type specimen is unusually broad at its narrowest point—36 mm. in comparison with No. 4321, in which the minimal width of the sagittal crest is only 21 mm. In the type, No. 1544, the vertex of the skull is broadly plane, but in No. 4321 the hinder part of the vertex is gently concave, the concavity being extended posteriorly as a sharply defined groove in the median line of the sagittal crest back almost to the point where the latter merges into the occipital crests. In No. 1544 the vertex passes uninterruptedly into the occiput by a gentle curve, there being no definite supraoccipital border. In the University of Kansas No. 4321 these relations are not present, the supraoccipital border being well defined. Both specimens agree closely in the width of the vertex: this dimension, just behind the orbits, is 136 mm. in No. 1544 and 135 mm. in No. 4321. Between the orbits the two specimens are 119 mm. and 118 mm. in breadth, respectively. A sharply defined difference in the two skulls is found in the greatest breadth of the nasals posteriorly, this being but 76 mm. in No. 1544 and 120 mm. in No. 4321; near the tips the two are nearly identical—47 mm. in No. 1544 and 46 mm. in No. 4321. This indicates a decidedly more sharply tapering snout in the University of Kansas specimen than in the type. In both specimens the palate is relatively short and broad, and not decidedly arched, though in the type Osborn describes the postnarial space as "relatively short and deep," while in the University of Kansas specimen the postnarial space is relatively long and deep. In both cases the postglenoid processes are transversely extended; the posttympanic process in No. 1544 is described as broadly oval, while in No. 4321 it is roughly rectangular or rhombic, with its surfaces decidedly rugose. In the type the paroccipital processes are relatively slender and acute, while in No. 4321 they are also compressed and posteriorly concave. In both specimens the inferior border of the molars has the form of a relatively sharp ridge—somewhat rugose in No. 4321—from the point where the arch leaves the skull to its junction with the squamosal. A mastoid foramen is observed on the occipital aspect of both skulls, but while described by Osborn as large in the type, it is small in No. 4321.

In the lateral view the American Museum of Natural History

specimen (No. 1544) has a prominent antorbital process on the lacrimals, which is present but less prominent in the University of Kansas No. 4321. In both cases the facial region is distinctly abbreviated; in No. 1544, the distance between the orbit and the narial notch is 70 mm., which, divided by the basilar length of the skull (415 mm.), gives an index of .1685+; in No. 4321 the corresponding distance is but 65 mm., which, divided by the basilar length of the skull (446 mm.), gives an index of .1457+. This is a significant progressive variation in the University of Kansas specimen. The absence of horn rudiments is common to both specimens, as well as the convexity of the maxillaries, the abbreviation of the premaxillaries, the shape of the molars, the rounded premaxillary symphysis, and the rounding and depression of the maxillaries below the narial notch above the third and fourth upper premolars. Both likewise have a diastema between the opposite incisor series, and behind both the incisors and the canines. They differ decidedly in regard to the presence or absence of an external cingulum on the last upper molar. Osborn describes this molar in No. 1544 as having a well-marked external cingulum, which is present but less distinct on the other molars also. In No. 4321 the molars, which are complete and practically without any sign of wear, have absolutely no trace of an external cingulum. This is a decidedly progressive character in No. 4321.

The fifth evolutionary stage of Osborn, represented by the American Museum of Natural History No. 1581, has horn rudiments on the frontals, which No. 4321 lacks; in both the facial convexity is very prominent and both have the progressive character of a distinct mesostyle on the fourth upper premolar. Osborn regards his specimen as a "mutation transitional to *Palæosyops robustus*," basing his conclusion upon the presence of the rugose horn-boss on a slight elevation involving a portion of both the frontal and the nasal bones and crossing the nasofrontal suture.

It is therefore desirable to compare the University of Kansas specimen (No. 4321) with *Palæosyops robustus*, especially so since *P. robustus* is from Bridger level D. Its specific characters, available for comparison with No. 4321, are given by Osborn as follows:

"Of massive breadth and proportions; slightly more brachycephalic than *P. major* and *P. leidyi*. Total length of skull [*i. e.*, basilar length], 440 mm. Zygomatic breadth, 340 mm. Length of premolar two-molar three series in upper jaw, 163-170 mm. Mesostyles variable on third upper premolar, more constant on fourth upper premolar. Molars with oblique ectolophs. Third upper molar enlarged, with prominent parastyle, ectoloph oblique, molar

conules strong. Distinctly rugose frontonasal horn swellings. Cephalic index. 77."

In comparison with *P. robustus, P. leidyi* is in general of smaller size, though the larger specimens of the latter species overlap the smaller of the former (Osborn, *op. cit.*, p. 316). The greatest recorded basilar length of the skull in *P. leidyi* is 415 mm. The zygomatic breadth has a recorded range of 275 to 310 mm. The upper length of the premolar two-molar three series in *P. leidyi* is 158 mm. Diastemata are present behind the canines. The posterior superior premolars have mesostyles. There are barely defined rudiments of osseous frontonasal horn-swellings on some specimens. Cephalic index, 74. In addition, Osborn stresses the presence in *P. leidyi* of *distinct external cingula, "all cingula heavier in specimens from the upper levels."*

Thus it should be noted that the University of Kansas specimen No. 4321 has a greater basilar length than any recorded even for *P. robustus*—446 mm. in the former *vs.* 440 mm. in the latter. The zygomatic breadth, however, is only 323 mm. as against 340 mm. in *P. robustus* and 275 to 310 mm. in *P. leidyi*. The cephalic index in No. 4321 is therefore 72; less than the 74 of *P. leidyi* and still less than the 77 of *P. robustus*. In short, it is less brachycephalic than either. Of the seventeen (17) dimensions given in the table (Table I), the University of Kansas No. 4321 resembles *P. leidyi* in eight and *P. robustus* in nine. But, four of these items are common to the two species. *It is therefore clearly intermediate between the two in these respects.* It resembles *P. leidyi* in the presence of diastemata behind the canines, but differs from that species in the *total lack of external cingula on its molars,* which it should possess if Osborn's dictum be correct that "all cingula [are] heavier in specimens [of *P. leidyi*] from the upper levels," where this specimen was collected. But *P. robustus* also is characterized by the possession of strong external cingula, hence in this respect No. 4321 differs from both, and is more progressive than either.

The absence of osseous horn-swellings would seem to remove the University of Kansas specimen entirely from *P. robustus,* which has "distinctly rugose horn-swellings," and to permit its affiliation with *P. leidyi,* in which these structures are either present or absent.

One could, on the basis of the differential characters cited above, justify the recognition of No. 4321 as a new species equally as valid as those accepted by Osborn, but it seems to the present writer that the situation permits another alternative, namely, to recognize

it and certain of Osborn's species as merely *subspecies* of one common species. Indeed, Osborn himself furnishes justification for this decision, which he recognizes as a possibility, when he remarks (*op. cit.*, p. 332) that—

"In addition to the specimens which exactly or very closely resemble Marsh's type [of *P. robustus*], there are others which appear to occupy an intermediate position between *P. robustus* and the older form of *P. leidyi* of level C."

And again (p. 332), when he notes that—

"Some of the less progressive forms [of *P. robustus*] are so much more primitive than the typical *P. robustus* that they might be placed with equal exactness in *P. leidyi*. They are especially interesting biologically in demonstrating the gradual inception of such specific characters as are seen in *P. robustus* rather than the sudden saltation of this species out of its predecessors."

In my opinion Osborn makes the correct suggestion, which, however, he did not himself adopt, that *P. paludosus, "P. major, leidyi,* and *robustus* form successive mutations which are very nearly if not quite in a direct line, which might perhaps have been designated by trinomial names such as *P. paludosus paludosus, P. paludosus major, P. paludosus leidyi,* and *P. paludosus robustus,"* to which we would now add *Palæosyops paludosus confluentus* as a fifth subspecies with the University of Kansas Museum of Vertebrate Paleontology specimen No. 4321 as the type.

The situation gives clear evidence that in this line of mutations, at least, the titanotheres underwent a gradual evolution in which all their characters varied in sundry directions—there was a slow accumulation of heritable variations rather than saltations—but so far as can be seen there is no evidence of the action of natural selection, at least in these more primitive forms. Rather there seems to have been a combination of inherited organization in structure and function with external factors that produced an orthogenetic trend, the explanation or cause of which is yet to be discovered. In this conclusion, which is also that to which Osborn's work led him, it is apparent that the paleontologist, no less than other biologists, has not yet been able to get at the fundamental, underlying factors that have been active in the evolution of the vertebrates.

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Concerning a Fossil Water Bug from the Florissant (Nepidæ).

H. B. HUNGERFORD, Lawrence, Kan.*

A FEW years ago my friend, George F. Sternberg, sent to me for determination two beautifully preserved fossils of a Nepa nymph which he had collected in the Florissant beds in Colorado.

One of these shows plainly by the well-marked median slit on the thorax and the U-shaped rupture on the head that it is the molted skin of a nymph. The larger of these two fossils is the same size and has the appearance of Cockerell's *Zaitha vulcanica* which he described and figured.[1] Doctor Cockerell's figure shows plainly that his specimen is a Nepa nymph and not a Belostomatid.† The shape of the pronotum, the head, the size and shape of the legs and the stout caudal appendages are all Nepa characteristics, as can be seen by examining the photographs on Plate XXVII.

I have reared both Belostoma and Nepa and have before me the four molted nymphal skins of a specimen of *Nepa apiculata* Uhler that I reared. Photographs of two of these are presented on Plate XXVII for comparison with the fossils. I believe that the smaller fossil is the molted skin of the second-stage nymph and that the larger one is the third-stage nymph of a Nepa. Since the larger one is the same as Doctor Cockerell's fossil, the species should be named *Nepa vulcanica* (Cockerell). This Miocene Nepa differs from our recent *Nepa apiculata* Uhler by its slightly larger size and longer front femora. If its growth ratios were relatively the same as for our modern species, and they appear to have been (1.33-1.4), then the adult *Nepa vulcanica* (Cockerell) must have been about 24.7 mm. long, not counting the respiratory filaments which would be slender and relatively much longer than in the nymph. The fol-

*Contribution from the Department of Entomology, University of Kansas.
1. *In* The American Journal of Science, Vol. XXV, March, 1908, p. 227.
† The name "Zaitha" was replaced by "Belostoma" several years before 1908.

lowing notes and figures are presented for purposes of comparison between the Florissant Nepa and our present North American species. The figures cannot be exact but are approximations.

W. E. Hoffmann[2] reported that *N. apiculata* Uhler has but four nymphal instars. Since he reared his specimens, both male and female, from eggs there can be no doubt about it. I have reared a considerable number of adults from first instar nymphs captured in Michigan, all with four molts. The European *Nepa rubra* Linn. (= *N. cinerea* Linn.) is said to have five nymphal stages.[3]

Adult males of Nepa are smaller than the females and there is a corresponding difference in the size of the older nymphs; therefore the measurements can be only approximations. I am assuming

	Length†	Width of abdomen	Length of front femur	Estimated spread of front femora‡	Length front tibia + tarsus‡	Length middle tibia and tarsus**	Length hind tibia and tarsus	Length hind tarsus + claw	Hind tibia
N. apiculata second-stage nymph	8.1	3.75	2.65	6.6	2.4	2.4	3.9	1.35	2.55
N. apiculata third-stage nymph	10.8	4.8	3.3	9	3	3.15	4.95	1.68	3.27
N. apiculata adult*	19	.....	.....	.....	.....	.....	.....	.....	.....
N. vulcanica smaller	9	3.6	3.3	8.4	3	3.?	4.2	1.2	3
N. vulcanica larger	12.6	4.8	4.2	9.6	3.9?	?	5.4	.....	.....
N. vulcanica adult*	24.7?	.....	.....	.....	.....	.....	.....	.....	.....

* Not counting respiratory tube. The nymphs are measured from tip of beak to tip of respiratory tube.
† All measurement in mm. ‡ Not straightened out. ** With claw.

that *N. vulcanica* (Cockerell) had four nymphal instars and if I am correct, fossil nymphs should be found in the Florissant beds measuring approximately 6.4 mm. for first stage and 17.6 mm. for fourth stage.

Dr. Anton Handlirsch, in his monumental work on "Die Fossilen Insekten," 1906-1908, records the family Nepidæ for the Jurassic, where it is represented by the genus *Mesonepa* Handlirsch. In this genus he places two species, *Mesonepa primordialis* (Germar) and *Mesonepa minor* Handlirsch. The former measures 28-30 mm. long and the latter 24 mm. On plate LI he figures both of these. Both of the drawings lack the respiratory tube as do all the specimens examined by him. Both species figured are adults and cer-

2. *In* Bulletin of the Brooklyn Entomological Society, XX, p. 93.
3. *See* Ossian Larsen *in* Entomologisk Tidskrift, 1930, p. 233.

tainly are Nepidæ. The absence of a respiratory tube in all the specimens makes it appear likely that this early genus lacked this specialization. There is a modern Nepa, *N. hoffmanni* Esaki with very short filaments. Several Nepa from the Tertiary (Lower Oligocene and Upper Miocene) are listed in this great work, only one of them named and that is labeled ?*Nepa atavina* Heer. Doctor Cockerell's *Zaitha vulcanica* is listed without comment by Doctor Handlirsch in the "Nachträge," p. 1359.

I believe that some day an adult *Nepa vulcanica* (Cockerell) will be discovered.

PLATE XXVII.

CONCERNING A FOSSIL WATER BUG.

All magnifications are × 2.84. Actual lengths shown by vertical lines.

1. *Nepa apiculata* Uhler. Molted skin of second-stage nymph. Actual length 8.1 mm.

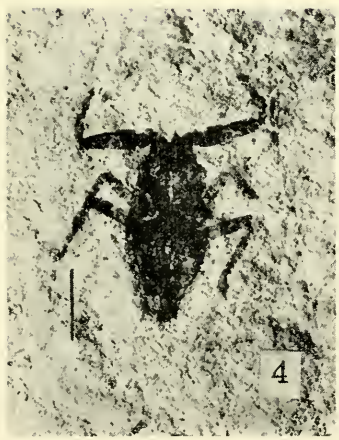
2. *Nepa apiculata* Uhler. Molted skin of third-stage nymph. Actual length 10.8 mm.

3. *Belostoma flumineum* Say, nymph. Actual length 15.5 mm. For many years the generic name Zaitha was used. This photograph shows the contrast between "Zaitha" and Nepa. Cockerell's *Zaitha vulcanica* is like the fossils shown in figures 4 and 5 of the plate and therefore should be named *Nepa vulcanica* (Cockerell).

4. *Nepa vulcanica* (Cockerell). Actual length of fossil 9 mm. Note the median longitudinal slit on the thorax as in the molted skin of *N. apiculata* figure 1. A molted skin (probably the second).

5. *Nepa vulcanica* (Cockerell). Actual length 12.6 mm. Probably the third instar nymph. Both fossils are from the Florissant of Colorado.

PLATE XXVII.



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Grasses and Other Plants from the Tertiary Rocks of Kansas and Colorado.

MAXIM K. ELIAS.

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SUMMARY.

THE fossil remains described in this paper represent protective covers of grains of true grasses and nutlets of herbaceous plants of the borrage family, accompanied by hackberry (*Celtis*) stones. The flora consists of the following forms:

GRASSES.

Panicum (sensu lata) *elegans* Elias n. sp.
Stipa kansasensis Elias n. sp.

BERRIOCHLOA Elias n. gen.
Berriochloa glabra (Berry) Elias n. comb.
Berriochloa (?) *aristata* (Berry) Elias n. comb.

HERBS OF THE BORRAGE FAMILY.

BIORBIA Elias n. gen.
Biorbia rugosa (Berry) Elias n. comb.
Krynitzkia (*Cryptantha*) *coroniformis* Elias n. sp.
Krynitzkia (*Oreocarya*) *chaneyi* Elias n. sp.
Krynitzkia auriculata Elias n. sp.

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ULMACEÆ.

Celtis cf. *willistoni* (Cockerell) Berry.

The plant remains were collected in Wallace county and adjacent territory and come from arenaceous and mostly unsorted continental deposits of early Pliocene age, which is indicated by the abundance of remains of *Pliohippus leidianus* and other typical vertebrates of this age buried in the same beds. These beds are considered by modern authorities to represent a flood plain environment of the Rocky Mountains piedmont. The remains of plants appear to be buried approximately at the place of their growth. They represent a rich and mostly herbaceous vegetation of semiarid prairies of early Pliocene time. The flora seems to indicate a somewhat warmer climate than that of to-day in the Great Plains region.

INTRODUCTION.

The described plant remains were collected by the writer in Wallace county, western Kansas, and in Yuma county, eastern Colorado, 1927-1928. Additional material was gathered in the autumn of 1929 and 1930 during exploration of Wallace county and other areas for the State Geological Survey of Kansas. The described material comes mostly from typical "mortar beds" of the Ogallala formation.[1]

The High Plains Tertiary is famous for its rich fauna of mammals, many of which were typical grazing, cursorial animals with teeth apparently adapted for the grinding of hard herbs. Fossil remains of these herbs have never been recorded until recently, however. As early as 1884 John B. Hatcher made a large collection of Tertiary fruits in Phillips county, Kansas, and deposited them in the United States National Museum. It was not until 1928 that this and additional material from Kit Carson county, Colorado, were described by E. W. Berry, who recognized part of the remains as stones of *Celtis,* revising the opinion of Williston and Cockerell that identical fruits from other localities belong to *Tithymalus* of the Euphorbiaceæ. The other fruits were described by Berry as nutlets of an extinct species of *Lithospermum,*[2] the living species of which herbaceous plant are now widely scattered in temperate and tropical zones.

Two out of the three varieties of *Lithospermum fossilium* Berry were collected by the writer and are referred in the paper to a true

1. For the description of this formation see Wallace County Report, Elias, 1931.

2. Miss Betty Watt Brooks also contributed a description of one of these fruits in 1928 and 1929 and referred it to *Celtis.*

grass *Berriochloa* (n. gen.) related to *Hordeum* and others and to a new extinct genus *Biorbia* of the Borraginoideæ-Anchuseæ subfamily of the borrage family. Among the new fruits collected by the writer two represent protective covers of the common grasses, *Panicum* and *Stipa*, while others are nutlets of three new species of *Krynitzkia* of the borrage family and *Celtis* stones identical with those described by Cockerell and Berry.

ACKNOWLEDGMENTS.

The work of preparation and identification of the collected material was done at the State Geological Survey and the Department of Botany at the University of Kansas. The writer was encouraged in his research on the stratigraphy and paleontology of the Ogallala by the state geologist, Dr. Raymond C. Moore, and the assistant state geologist, Dr. K. K. Landes. Due to absence of literature on similar fossil forms[3] a detailed comparison with living plants was the only way in which to undertake a better classification of the scant but beautifully preserved remains. Help in securing fruits of living herbs was rendered by Messrs. R. W. Chaney, F. H. Hillman, A. S. Hitchcock, W. H. Horr, C. E. Leighty, John Percival, J. B. Reeside, Jr., Eleanore M. Reid, P. A. Rydberg, H. C. Skeels, W. C. Stevens, and Emma E. Syrrine, to whom the writer wishes to extend sincere appreciation. Without their help, so cordially rendered, this work could not have been accomplished. The botanical part of the manuscript has been read by W. C. Stevens and the whole manuscript by R. C. Moore, to whom sincere thanks are due.

All sketches were made by the writer and represent actual and not generalized views of the fruits. The microphotographs were also prepared by the writer in the photo laboratory of the State Geological Survey.

PREVIOUS WORKS ON FOSSIL HERBS.

The literature on fossil grasses and other herbaceous angiosperms is not large and is much scattered. As far as known to the writer, the remains of these plants have never been a subject of special study, though incidental descriptions of fossils resembling modern grasses, rushes and other herbaceous angiosperms can be found in some papers dedicated to the remains of trees and shrubs of late Cretaceous Tertiary, and Quaternary times. The grasslike remains which have been found occasionally among the foliage of arboreal

3. Except the above referred pioneer work by Berry and Brooks.

types, which comprise the bulk of paleobotanical collections, usually consist of fragmentary linear leaves and herbaceous stems, the reference of which to this or that genus of living grasses is in most cases quite arbitrary. The determination of meadow grass (*Poacites*) from the Tertiary of Greenland by so able a paleobotanist as Heer[4] was criticized by Gardner[5] and other botanists, while the occurrence in the Tertiary of *Oryza, Panicum,* and other genera of typical prairie and pampas grasses, was also regarded as questionable. Engler[6] concludes that only the presence of *Arundo, Phragmites* and perhaps of *Bambusa* was established on sufficient fossil evidence. Among the very best remains of fossil Gramineæ ever recorded are leaves and stems accompanied by well-preserved fruits from the "Lower Green River" formation of Colorado described by Lesquereux[7] and referred by him to *Arundo,* the common reed grass of to-day.

In the last two decades several papers by Eleanore M. Reid, Jules Welch and other European authors have appeared, describing large collections of fossil seeds and fruits from the Pliocene and late Miocene of England and western Europe. Various types of Cyperaceæ were recognized, always associated with remains of mosses and with a considerable number of fruits of trees, shrubs and marsh and water herbaceous angiosperms.[8] Not a single species resembling xerophytes of the grass and borrage families has been recognized among these remains, which is not surprising, as the whole assemblage indicates moist and not semiarid soil conditions.

The records of fossil herbs of the borrage family are also very scarce and the identifications are established mostly on questionable grounds. Fruits resembling some simple-sculptured nutlets of the borrage family were described by Heer and Ettingshausen from Middle European Miocene and named *Borraginites* and *Heliotropites* respectively. However, as Gürke[9] justly remarks, no ring at the base of these fruits can be detected, and therefore they may belong to some other families as well. The remains of a little flower, from the same formation, which was named by Heer *Borraginites myosotiflorus,* resemble flowers of Borraginaceæ, indeed, but the exact relation of these scant remains to the family is far from being clear. The presence of Borraginaceæ in the Pleistocene is estab-

4. Heer, 1883, p. 67.
5. Gardner, 1886, p. 441.
6. In Hackel, 1887, p. 16.
7. Lesquereux, 1887, pp. 86-91.
8. Reid, 1920.
9. Gürke, 1897, p. 80.

lished on better grounds, fruits of *Myosotis cæspitoza* being known in the Pleistocene of Norfolk and nutlets of *Lithospermum* being recorded from the Pleistocene of Illinois.

Fruits and leaves of *Cordia* of the Borraginaceæ from the Tertiary of Colombia and other areas have been described by Berry and other authors, but the living species of *Cordia* are trees and shrubs, which are classified with the herbaceous plants of the borrage family on the ground of similarity of flowers and fruits.

It is probable that a diligent search through the Tertiary sediments of semiarid valley-flat environments in North America and elsewhere will disclose more remains of the types described in this paper, as they are far from rare in the Ogallala formation of Kansas and northeastern Colorado. Barbour, who described good specimens of Celtis stones from the Tertiary of western Nebraska, points out the great abundance and variety of "seeds and nuts" in the Tertiary, and especially in the Miocene, of Nebraska.[10] It is true that they are inconspicuous and not as easy to find or to collect as the more ordinary assemblages of fossil plant remains.

OCCURRENCE.

The fossil fruits of the Ogallala were collected from poorly sorted grayish-pink semicemented grit and loam, which constitute the larger portion of the formation. The remains of fruits are scattered through the rocks and are small, being from two to three millimeters, or rarely up to one centimeter in length. They are snow-white and some are made of silica (probably opal) while others are composed of calcium carbonate. This is very unlike the ordinary occurrence of fossil plants (leaves and other parts) which are commonly collected in fine-grained sedimentary formations, such as fine sands, marls, volcanic ash and especially clayey rocks, and the color of which (chiefly leaves) in these rocks is usually darker than the matrix and often the remains are black, dark brown or otherwise darkly colored.

It is noteworthy that no fruits of any kind were found by the writer in fine sands, marls or clayey beds of the Ogallala though a special search through all available exposures of these beds was made. To the contrary the Ogallala fossil fruits in Wallace county and adjacent area are abundant in beds of grit and loam even where a considerable quantity of small pebbles is noticed in the material of these rocks. In spite of the presence in the rock of coarse grains

10. Barbour, 1925, pp. 87-88.

and even pebbles, the fossil fruits scattered among this coarse material usually show little abrasion of their delicate outer sculpture. This indicates that the fruits were not transported with debris from the Rocky Mountain area, but probably were buried in the sediments when their (sediments) transportation was nearly finished. It appears as if the fruits were dispersed by the aid of wind or animals, were scattered upon the ground, but for some reason, perhaps due to too large a loss of water, did not germinate and were mixed up and buried with the next portion of debris which mantled the prairie.

Dr. G. L. Knight, of the University of Kansas, has made an interesting discovery of fossil fruits in the Tertiary volcanic ash in Norton county, Kansas, and has kindly submitted the material to the writer for study. The flora consists of the following forms:

Celtis sp., probably *willistoni* (Cockerell) Berry.
Krynitzkia (*Cryptantha*) *coroniformis* Elias.

Dr. C. F. Taylor, superintendent of the State Sanatorium for Tuberculosis, generously donated through the writer to the University of Kansas remains of two large carapaces of a turtle which have been found in the same bed of volcanic ash. The remains seem to belong to *Testudo* (*Xerobites*) *farri* Hay, a late Tertiary turtle of Montana. The plant remains indicate Upper Pliocene age for the volcanic ash of Norton county. Knight considers that the ash of this locality was deposited in a small lake.[11]

Fragments of small-diameter hollow stems (Pl. III, Fig. 8) were collected by the writer in a bed of greenish sand in the Ogallala formation directly below a thin bed of white limestone which contains diatoms and molds of gastropods. These stems are smooth and bear a faint and very regular longitudinal striation, and in some of the fragments very distinct joints are observed. Altogether they look like straw and can hardly belong to any other plants except true grasses.

Some peculiar stem and rootlike bodies made of calcium carbonate were observed in many "mortar beds" of the fossil herbs zone. These calcareous formations are white, cylindrical, slender, straight or somewhat irregularly curved, from a few millimeters to two or three centimeters wide. Usually they are nearly or quite erect or they are horizontal. They are scattered through some of the typical semicemented "mortar beds," but in some exposures they appear in great number at the top of escarpments and form a tangled labyrinth somewhat similar to the roots in ordinary sod, but much larger in

11. Knight, 1931, p. 166.

scale.[12] The stem and rootlike bodies do not have enough structural features to permit identification of any particular kind of plants. Nothing like joints has been observed in either the smaller or larger cylindrical bodies. These are invariably smooth or only gently and irregularly striated on the outside and are solid inside, usually with an irregular porosity in the middle. They can hardly belong to true grasses, but they may represent stems and roots of some other plants, the original anatomy of which has been nearly destroyed during fossilization. No foliagelike organs or fruits of any kind have ever been observed on or near these bodies, but often fruits occur in the nearest beds above or below in the section.

The fossil fruits usually appear in the form of hollow nutlets with thin and often fragile walls.[13] Sometimes they are cracked and fall apart as soon as separated from the matrix, and often only fragments of the fruits can be seen in the rock.

Often the fruits are scattered in a bed, but occasionally they are crowded in a spot, sometimes forming a sort of a cluster. This is particularly the case with the *Celtis* stones, this mode of occurrence being suggestive of ejection by some animals that fed on them. Identical fruits have been found in the skull of a land turtle.[14] Nutlets of *Biorbia rugosa* (= *Celtis microendocarpica* Brooks) have been found in the brain case of a skull of *Teleoceras fossiger* (Cope) from the Long Island quarry, Phillips county, Kansas.[15]

The foliage of a rich arboreous flora has been collected and reported by Cragin[16] and later by Case[17] from the Tertiary diatomaceous marl of Beaver county, Oklahoma, which borders the Kansas state line. These plant remains belong to the same age as the herbaceous flora described in this paper, or are of a slightly older age. In the small collection donated by E. C. Case to the United States National Museum Berry[18] identified and described the following forms:

Cyperacites sp.
Caulinites sp.
Salix sp.
Platanus aceroides Goeppert.
Gymnocladus casei Berry.
Sapindus oklahomensis Berry.
Rhamnus lesquereuxi Berry.
Bumelia oklahomensis Berry.
Diospyros brachysepala Al. Braun.

12. See Elias, 1931, Pl. XXVIII.

13. Only in one case internal molds of *Celtis* stones have been collected, and these were found in a thin streak of pinkish sandy limestone near the top of Ogallala.

14. See occurrence of *Tithymalus willistoni-Celtis willistoni* (Cockerell) Berry in Osborn, 1910, p. 342.

15. Brooks, 1928, p. 299.

16. Cragin, 1891, p. 29.

17. Case, 1894, p. 143.

18. Berry, 1918, pp. 627-636.

A richer collection of the same flora and from the same locality was deposited by Case at the University of Kansas and includes, besides some of the forms described by Berry, *Populus balsamoides* Goeppert (Pl. XXX, Fig. 6, this paper) and a variety of species of *Betula, Populus, Salix* and other arboreous vegetation now being studied by the writer. This mesophytic vegetation is regarded by Berry as of upper Miocene age, but he adds that "there is no conclusive evidence in existence that such a valley flora may not have continued in this region during the early Pliocene, there being no considerable American Pliocene floras, except that of the Gulf coast, with which to make comparisons."

The writer found one fragment of *Populus* cf. *balsamoides* Goeppert (Pl. XXX, Figs. 7*a*, 7*b*) in the diatomaceous marl of undoubted upper Pliocene age at the Marshall ranch in Wallace county,[19] and an effort to collect more flora from these beds will be made by him.[20] The above referred fragment of a leaf of poplar was found in diatomaceous marl a few feet above the sand in which a rich fauna of vertebrates, chiefly mammals (*Pliohippus leidianus* and others), has been collected by H. T. Martin and referred to the lower Pliocene. This is an interesting bit of evidence that a mesophytic valley-flora existed in a few places of the Great Plains in Lower Pliocene time. By far the greatest part of the area of the Great Plains was, however, covered by a different, xerophytic and chiefly herbaceous, vegetation, numerous remains of which, mostly in the form of fruits as mentioned above, are very common in the regular unsorted arenaceous deposits of the Lower Pliocene. These beds are considered by modern authorities to represent a flood plain environment of the Rocky Mountains piedmont. The typical prairie and savannah flora which covered the greatest area of the piedmont in early Pliocene time included the following forms:

Panicum elegans
Stipa kansasensis
Berriochloa glabra
B. (?) *aristata*
Biorbia rugosa
Krynitzkia coroniformis
K. auriculata
K. chaneyi
Celtis willistoni

This assemblage seems to indicate a somewhat warmer climate than that of to-day in the Great Plains region.

19. Elias, 1931.

20. C. W. Hibbard, who assisted the late H. T. Martin in excavation of vertebrates at the Marshall ranch locality, related to the writer that he uncovered some impressions of dicotyledon leaves in diatomaceous marl, but they disintegrated by the time he came to collect them.

DESCRIPTION OF SPECIES.

PHYLUM *SPERMATOPHYTA*

CLASS ANGIOSPERMÆ.—SUBCLASS MONOCOTYLEDONÆ.—ORDER GLUMIFLORÆ.

FAMILY GRAMINEÆ (GRASSES).

Annual or perennial herbaceous (rarely woody)[21] *plants, with usually hollow cylindrical and jointed stems; usually linear, parallel-veined leaves; flowers without any distinct perianth, mostly hermaphrodite (bisexual), arranged in panicles, racemes or spikes; each flower provided with green bracts (glumes); fruit is the characteristic caryopsis or grain.*

To this family are referred three types of fruits from the Ogallala formation described below. No stems or leaves have been found in direct connection with these fruits, and, therefore, the herbaceous nature of the plants which bore the fruits cannot be directly demonstrated. However, all the living species of Gramineæ which bear similar types of fruits are typical herbs.[22]

The fossil fruits consist of fertile glumes or lemmas and pales or paleas only, the starchy caryopsis being not preserved. Rarely inside of the glumes can be seen a thin semitransparent film which most probably corresponds to the pericarp of a caryopsis.

The protective cover of a grain of a grass is but a small integral part of the whole plant, but it is an important part from a taxonomic point of view. The characters presented by the spikelets or inflorescence are usually employed in defining the genera of grasses, and, according to A. S. Hitchcock, it is the protective fertile glume or lemma, "which is of great importance in classification, its shape, texture and nerving being uniform within definite limits in any given genus."[23]

The fruits of grasses from the Ogallala formation are so well preserved that not only the characteristic shape, but also the keels or nerves and all minute details of texture can be readily observed and examined under proper magnification. Due to perfect preservation of these vital portions of the fossil grasses, their comparative study with the living forms and their classification can be made with a considerable degree of accuracy.

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21. Tropical Bambuseæ are tree size and have woody stems.

22. Fragments of stems indistinguishable from those of living grasses have been collected in some beds, as referred above (Pl. XXX, Fig. 8). This is another, though indirect evidence that the fruits of Graminæ type which were found in other beds of Ogallala were of herb size.

23. Hitchcock, 1914, p. 124.

Subfamily PANICOIDEÆ.—Tribe PANICEÆ.

Genus *Panicum* Linnæus.

Panicum (sensu lata) *elegans* Elias n. sp.

(Pl. XXVIII, Figs. 2*a*, 2*b*, 2*c* and 4.)

Only the protective cover of caryopsis is known. Lemma and palea smooth, shiny, connected together to form protective cover of grain. Length of fruit, 2½ mm., width across lemma, 1¾ mm.; thickness of fruit, 1¼ mm. Apex cuspidate with two more smaller cusps, one on each side of the middle point, which is most prominent. These three points are somewhat continued down the lemma and form gradually flattened ridges, which correspond to three principal veins of the lemma (Fig. 2*a*-A).

Lemma much more inflated than palea. Palea with two distinct keels (nerves) which are not concealed by the margins of the overlapping lemma. At the base of the lemma is a lunar elevation (Fig. 2*a*-B). Similar elevations on the protective covers of living *Panicum* and allied genera are impressions of the embryo, the radicle protruding through these at germination.[24] Scar of attachment nearly flat, inclined to the side of the palea, trilobate on the opposite side (Fig. 2*c*-D). According to examination of the writer's sketch by A. S. Hitchcock "the shape of the scar is likely to be characteristic of the species."[25] In the middle of the scar is a little hole which, according to Hitchcock, is a scar of the fibrovascular bundle (Fig. 1*c*-E). The remains are composed of silica, the walls of lemma and palea being 0.035 mm. thick.

Faint subparallel striation can be seen on both lemma and palea under magnification. Microphotographs of corresponding portions of the palea of the fossil form and of the living *Panicum angustifolium* were made for a comparison of microstructure (Pl. XXVIII, Figs. 4 and 3). Both show subparallel rows of cells of the epidermis. The distance between two striæ on the palea of *P. elegans* is 0.034 mm., and on the palea of *P. angustifolia* 0.029 mm. These figures belong to the middle portions of the paleas. The striæ show a confluence in both apical and basal directions. Regularly spaced cross connections between the striæ can be seen on both fossil and living forms.

The fossil fruit is indeed strikingly similar to the protective cover of the caryopsis of living species of *Panicum* and allied genera:

24. Hitchcock and Chase, 1910, p. 18.
25. Personal communication to the writer.

Chætochloa (*Setaria*), *Echinochloa*, *Paspalum*, *Milium* and others. The palea of the fossil fruit is, however, considerably more inflated than in most of the similar fruits of living species. Due to this the two keels of the palea are seen along their whole length in the fossil fruit, while in the majority of living species the keels of the palea are hidden by the edges of the overlapping lemma.

The appearance of the exposed keels on the palea of some specimens of *Chætochloa italica* was pointed out by Hitchcock,[26] and a similar appearance of two keels of the palea can be noticed on some species of *Panicum* also. According to statement by Hillman, of the United States Department of Agriculture Seed Laboratory, the presence of ridges at the tip of the lemma indicate *Setaria,* but on the other hand "he does not know of any species of that genus that has a scar of the shape of the fossil fruits." [27] This scar of attachment resembles more the scars of the living species of *Panicum.* The general form of the fossil fruit also resembles very much the fruits of *Panicum fasciculatum* (Pl. XXVIII, Fig. 1) and of some other species of the Geminata group,[28] but all the fruits of this group have a rugose surface, while the fossil fruit is perfectly smooth. This smoothness is undoubtedly original, and not the result of abrasion, because all sharp cusps and edges of the thin protective cover are perfectly preserved.

All in all, the fossil form combines features of both *Panicum* and *Setaria* and is certainly closely related to these genera. In the time of Linnæus and earlier botanists the name *Panicum* was applied to *Chætochloa italica* and many other species now referred to different genera and subgenera, allied to *Panicum* s.s. Though the advisability of recognition of *Chætochloa* (*Setaria*) as a separate genus of Paniceæ is now shared by most of botanists, the Setarias still "might, under a broad conception of the genus Panicum, be referred to it."[29] It appears to be convenient, therefore, to describe the fossil form under the name *Panicum* with an understanding that this generic name is used in a broad sense. It is possible, however, that the fossil form belongs to a new genus or subgenus of Paniceæ, either extinct or not yet found or recognized among the living species of the tribe.

The living Paniceæ are largely tropical and subtropical grasses, few genera belonging to temperate zones. *Panicum* occurs in all

26. Hitchcock, 1914, p. 195.
27. Personal communication by A. S. Hitchcock to the writer.
28. Hitchcock and Chase, 1910.
29. Scribner and Merrill, 1900, p. 6.

warm countries, but together with *Paspalum* is a characteristic South American savanna grass.

OCCURRENCE OF FOSSIL FRUITS. Found in sec. 21, T. 14 S., R. 39 W., Wallace county, Kansas, in "mortar beds" of the Ogallala formation, Tertiary, about 40 feet below caping pink algal limestone. (See writer's report on the Geology of Wallace county, Bulletin 18, Kansas Geological Survey.)

Subfamily POACOIDEÆ.—Tribe AGROSTIDEÆ.

Genus *Stipa* Linnæus.

CHARACTER OF FERTILE FLORET. Rachilla articulate above the empty glumes and produced below the flowering glume into a strong, bearded, obconical and sharp-pointed callus. Lemma narrow, subcoriaceous, closely rolled around the flower and usually shorter palea, terminating in a twisted and geniculate, simple awn which is articulate with its apex. Grain closely enveloped by the hardened lemma.[30]

Stipa kansasensis Elias n. sp.

(Pl. XXVIII, Figs. 5*a*, 5*b*, 6, 7, 8, 9 and 12.)

Only the fertile glume (lemma) preserved, cylindrical, 10 to 11 mm. long and 1.8 to 2.5 mm. wide. The surface of the lemma is covered with tubercles from the apex to the middle or beyond. It seems that along some portions of the rolled lemma tuberculation descends down nearly or quite to the base (Pl. XXVIII, Fig. 9). The inner volution of the lemma seems to be tuberculate to the base, while the outer volution is smooth at the base and narrows gradually into the conical hairy callus (Pl. XXVIII, Figs. 6 and 9). The hairs which surround the callus are exceedingly thin and fragile, being as fine as in the living *Stipa*. At the top of the fossil form there is a distinct bottle-necklike contraction (Pl. XXVIII, Figs. 7 and 8) forming a joint to which apparently an awn was connected. This joint is surrounded by short bristles very similar to those on some living species of *Stipa*. (Compare upper portions of microphotographs of *S. kansasensis* and *S. reesiana*, Pl. XXVIII, Figs. 12 and 11.)

The presence of a joint at the apex of the cylindrical or cigar-shaped fertile glume distinguishes the fruits of living *Stipa* (Pl. XXVIII, Fig. 10) from those of *Andropogon, Aristida and Mühlen-*

30. Modified after Scribner—1900, p. 62.

bergia, which also have a subcylindrical lemma, but one that narrows gradually to the apex, in some cases is covered with tubercles and shows a hairy callus at the base. The lemmas of these fruits gradually pass into an awn without forming a joint.

Examination of the surface of the fossil form (Pl. XXVIII, Fig. 12) reveals a microstructure strictly similar to that of living species of Stipa (Pl. XXVIII, Fig. 11). The surface is covered with comparatively prominent tubercles which are not arranged in regular rows but are rather irregularly though densely spaced. The smooth surface between the tubercles as well as outside the tuberculate portions of the lemma shows faint striation corresponding to the rows of cells of the epidermis. On meeting a tubercle the striæ expand slightly, the marginal ones bending around the tubercle. The absence or presence of tubercles over the whole or only a part of the surface of the lemma, the size of the tubercles and the density of striation seem to be of specific value for species of *Stipa.* In the fossil form about 59 striæ can be counted in 1 mm. on the tuberculate portions of the lemma, while on the surface bare of tubercles there are up to 77 striæ in 1 mm. The diameter of the tubercles is 0.06 to 0.07 mm., one tubercle covering four rows of cells. The height of the tubercles is about 0.04 mm. above the striated surface. The thickness of the lemma, which is composed of silica, is about 0.035 mm., not counting the tubercles.

For comparison the corresponding structures of two living species of *Stipa* were measured. *Stipa neesiana* Trin. (Figs. 10 and 11) shows about 55 striæ in 1 mm. The tubercles are only a fraction wider than a row of cells, being about 0.02 mm. in diameter. They are confined to the apical portion of the lemma, about five-sixths of the surface being smooth and marked only with striations. *Stipa avenacea* L. has about 110 striæ in 1 mm. The tubercles average 0.035 mm. in diameter, each covering about 4 rows of cells. All the surface is tuberculate except the base, where tubercles gradually decrease in prominence.

The living *Stipa* belongs to tropical and temperate zones, being chiefly prairie, steppe and savanna grasses.

OCCURRENCE OF FOSSIL FRUITS. Found in the middle of the western border of sec. 4, T. 12 S., R. 42 W., Wallace county, Kansas, in "mortar beds" about 60 feet above the base of the Ogallala formation.

Tribe HORDEAE?

Genus *Berriochloa* Elias n. gen.

The species for which this new generic name is proposed was originally described by E. W. Berry under the name *Lithospermum fossilium* var. *glabrum*. The construction of the fossil fruits, as the writer's study reveals, is, however, of the type observed on the living grasses only. The characteristic features of the fruits of the genus are as follows:

Fruit consists of two glumes, the larger, the fertile glume or lemma, overlapping the smaller glume or pale or palea. The two glumes combine to form what is known as protective cover of caryopsis (grain). The latter is not preserved in a state of fossilization except its thin pericarp. The protective cover is provided with an awn at the apex and with a somewhat elongated scar of attachment at the base. The fruit is round in cross section, but the presence of five longitudinal ridges on lemma tends to make the cross section slightly subangular. Very rarely two faint longitudinal ridges can be observed in palea. It is appropriate to note that the palea of living grasses is always two-nerved.

In better preserved specimens fine and regular longitudinal striation can be seen on both lemma and palea. This is again a very typical feature for the protective cover of the grasses. In addition to longitudinal striation a more prominent but irregular transverse wrinkling is observable on all or nearly all fossil fruits in question. A similar transverse wrinkling exists on the protective covers of many living species of *Panicum* and of some other grasses.

The fossil fruits resemble in many respects the protective cover of cultivated barley (*Hordeum sativum*). They are of nearly the same size, are provided with an awn and their lemmas are five-nerved, a feature generally typical for genus *Hordeum*.[31] On the other hand the fossil fruits are much less angular in shape than the fruits of all living *Hordeæ* and are provided with a comparatively narrow and elongated, bottle-necklike scar of attachment, a feature uncommon in *Hordeæ* or in other grasses of to-day. This distinction warrants separation of the fossil fruits under a new generic name.

The classification of *glabrum* fruits with living grasses was one time criticized by Mrs. Eleanore M. Reid, with whom the writer conferred on the matter. However, after having seen the best-preserved specimens of the writer's collection sent to her, on which

31. Scribner, 1900, p. 165.

the details of microstructure are observable, Mrs. Reid agreed with the writer in his referring of *glabrum* to true grasses.

The writer acknowledges, also, the suggestion made by Dr. John Percival, to whom he has sent a sketch of *glabrum*, that this fruit can hardly be classified with *Hordeum*, but is possibly a *Panicum*. The communication with Mrs. Reid and Mr. Percival clarified the matter of proper classification of *glabrum* considerably and induced the final decision of the writer to give the fruits a new generic name. The genus is named after Prof. E. W. Berry.

Berriochloa glabra (Berry) Elias n. comb.

(Pl. XXVIII, Figs. 13*a*, 13*b*, 13*c*, 14, 15 and 16; Pl. XXIX, Figs. 1*a*, 1*b* and 1*c*.)

1928. *Lithospermum fossilium* var. *glabrum* Berry. Proc. U. S. Nat. Mus., Vol. 73, Art. 13, p. 2; Pl. 1, Figs. 11, 12 and 13.

Only protective cover and pericarp of caryopsis known.

Lemma and palea smooth, shiny, in state of fossilization usually firmly connected together and making an asymmetrically fusiform fruit. The larger specimens (Pl. XXIX, Fig. 1*a*, *b*, *c*), which are most abundant, are up to 7 mm. long (without awn) and up to 3.2 mm. wide, but much smaller individuals (Pl. XXVIII, Fig. 13*a*, *b*, *c*) are frequently found together with larger types. The lemma of larger specimens is distinctly five-keeled. The middle keel or nerve is most prominent and runs from the base to the very apex of the lemma, where it passes into an awn, only a small basal portion of which is preserved (Pl. XXIX, Fig. 1*b*-D). The back of the lemma with the prominent middle keel (Pl. XXIX, Fig. 1*a*-B) attached to it is shaped much like a boat. The lateral nerves (Fig. 1*a*-B) are about two times less prominent than the middle keel and are almost indistinct near the apex of the lemma. Two lateral nerves can be seen on one photograph[32] of *Lithospermum fossilium* var. *glabrum* Berry, which helps to identify our fossil with this type. On the smaller specimens of *B. glabra* (Pl. XXVIII, Fig. 13*a*, *b*, *c* of this paper and Fig. 11, Berry, 1928) only the middle keel is quite distinct, the lateral nerves being observed only as small ridges at the narrow base of the lemma (Pl. XXVIII, Figs. 13*b* and 13*c*).

The two nerves of the palea can be observed, also, on the larger types only (Pl. XXIX, Fig. 1*b*-D), being even there quite faint. A very gentle marginal bend on both sides of the palea, outside of the nerves, can be seen.

The smaller specimens are commonly found together with larger

32. Berry, 1928, Pl. 1, fig. 12.

types and, being not as fragile as the larger ones, the complete specimens of smaller types are predominant in the collection of the writer. The smaller types do not seem to represent younger stages of large fruits, but are more likely dwarfed mature fruits of the same species, unless they represent a distinct species of the same genus. They are as thick-walled as the larger specimens and have the same type of structure except that the keels are not as prominent. Also they appear to be more plump, being nearly as wide as the larger forms, but much shorter. The intermediate forms between larger and smaller specimens seem to exist. Possibly the smaller fruits occupied the apical portion of a spike and have been undernourished, being otherwise normal fertile florets. A similar arrangement of gradually diminishing fruits toward the apex of the spike is observed in some living grasses (compare, for instance, *Bouteloua*). The comparatively large per cent of smaller fruits seems to indicate rather short spikes with small number of florets rapidly decreasing in size toward the apex. If the future study should prove that the smaller fruits belong to a different species, the name *glabrum* is preferable to retain for the larger form, figures 12 and 13 (Berry, 1928) and figures 1*a*, 1*b* and 1*c*, Plate XXIX of this paper.

The microscopical examination of the remains reveals the following features (Pl. XXVIII, Figs. 15 and 16). The surface of the lemma and palea are smooth with occasionally observable fine and regular longitudinal striation (Pl. XXVIII, Fig. 15), about 35 to 40 striæ to 1 mm. on larger specimens and 40 to 45 striæ per mm. on smaller specimens; besides this, short transverse wrinkles can be nearly always observed over the whole surface of the fruits (Pl. XXVIII, Fig. 16). When the outer epidermis exfoliates the internal structure of lemma becomes visible. It consists of longitudinal ridges with cross connections in between. These ridges seem to correspond to the gentle striæ of the external surface (Pl. XXVIII, Fig. 15).

The fruits are hollow and are made of silica. The thickness of the lemma varies from 0.12 to 0.16 mm. within the same specimen. Inside of one broken specimen a very thin semitransparent film was observed—an empty wrinkled baglike envelope which is probably the pericarp of the caryopsis. The structure of the film is shown on pl. XXVIII, fig. 14. The black portions correspond to transparent tissue with less transparent white ridges between.

DISTRIBUTION OF FOSSIL FRUITS. Specimens are found at several localities in Wallace county, Kansas. (1) South side of Goose creek,

one-half mile west of the state line, in a bed about 60 feet above the base of the Ogallala. (2) In the southeast quarter of sec. 4, T. 12 S., R. 41 W., in beds 40 to 60 feet above the base of the Ogallala. (3) In the southeast quarter of sec. 7, T. 14 S., R. 38 W., in a bed 30 feet below algal limestone and 55 feet above the base of the Ogallala. The species is also observed in other parts of Wallace county in the middle portion of the Ogallala. The specimens described by E. W. Berry[33] were collected in 1884 by J. B. Hatcher from the "Loup Fork formation" of Phillips county, Kansas, which is Ogallala.

Berriochloa? aristata (Berry) Elias n. comb.

1928. *Lithospermum fossilium* var. *aristatum* Berry: Proc. U. S. Nat'l Mus., Vol. 73, Art. 13, p. 2; Pl. 1, Fig. 14.

This fruit described and figured by Berry has many features in common with his *L. fossilium* var. *glabrum,* now considered by the writer to represent a new genus *Berriochloa.* According to Berry *B. aristata* differs from *B. glabra* in being more slender and elongated, more symmetrical in side view and nearly circular in transverse section. The base is much like that of *B. glabra,* while "the apex is produced as an attenuating spine which may be two-thirds as long as the inflated portion." The spine or awn of *B. aristata* is certainly much more prominent than that of the other form and is about 1 mm. in width at the base, or two times wider than the awn of large specimens of *B. glabra.*[34] The keel of the *B. aristata* fruit is less elevated than that of *B. glabra;* the length of its fruit, exclusive of the awn, ranging from 5 to 10 mm. and the diameter from 1.5 to 3 mm.[35]

The species *aristata* described by Berry was not found by the writer in the Ogallala beds of Wallace county and adjacent area. The photograph by Berry shows only the dorsal view of the fruit, and therefore the presence or absence of lateral ridges on what appears to be a lemma, and the presence or absence of an inclosed palea cannot be detected. The general similarity of the form with the fruits of *Berriochloa glabra,* the base, middle keel and awn of the two species being much alike, suggests a reference of the species *aristata,* also to genus *Berriochloa.* However, this conclusion cannot be proved without additional examination of the type material.

OCCURRENCE. "Loup Fork" (Ogallala) formation of Phillips county, Kansas, together with *Berriochloa glabra.*

33. Berry, 1928.
34. Measured by the writer on the photograph by Berry.
35. After Berry, 1928, p. 2.

SUBCLASS DICOTYLEDONÆ.—SERIES GAMOPETALÆ.—ORDER TUBIFLORÆ.

FAMILY BORRAGINACEÆ.

Specialized dicotyledons with an elongated corolla tube bearing the stamens, the ovary being superior. Fruit mostly of four one-seeded nutlets.

Subfamily BORRAGINOIDEÆ-ANCHUSEÆ Gürke.

Genus *Biorbia* Elias n. gen.

Only nutlets known. Nutlets keeled, asymmetrically inflated, being more convex on the dorsal side. Surface rugose covered with ridges arranged in honeycomblike net. Dorsal keel turns to right or to left, spoiling the apparent bilateral symmetry of the nutlets. Probably four nutlets, two right and two left ones, constituted a complete fruit. Scar of attachment round, comparatively small and elevated, consists of double ring and an elaiosome in the center. Distinct canal in the ventral part of the scar.

Geno-type: *Lithospermum fossilium* var. *rugosum* Berry. U. S. National Museum.

Biorbia rugosa (Berry) Elias n. comb.

(Pl. XXIX, Figs. 2*a*, 2*b*, 2*c*, 2*d* and 2*e*.)

1928. *Lithospermum fossilium* var. *rugosum*, Berry, U. S. Nat. Mus., Vol. 73, Art. 13; Pl. 1, Figs. 1-10.

1928. *Celtis microendocarpica*, Brooks, Annals Carnegie Mus., Vol. XVIII, p. 297; Pl. XVIII, Fig. 1.

1929. *Celtis microendocarpica* Brooks, Annals Carnegie Mus., Vol. XIX, p. 135; Pl. IV, Figs. 1-9.

On account of the existing difference in opinions as to classification of these fossil fruits, the writer made a detailed study of their anatomy and an extensive survey among those living plants which could be their possible relatives. The fossil fruits have been described by E. W. Berry and by Betty Watt Brooks, who referred them to *Lithospermum* and to *Celtis*, respectively. The writer agrees with Berry that the nutlets in question belong to the borrage family, of which *Lithospermum* is one of the most common among the native American representatives. The writer concludes, however, that the fossil nutlets do not belong to *Lithospermum*, but must be classified with the Borraginoideæ-Anchuseæ group of Gürke, none of the genera of which group are native to the New World.

None of the living species of *Lithospermum* are known to have a

sculpture comparable to the honeycomblike net of ridges which covers the surface of the fossil nutlets. The surface of the nutlets of living *Lithospermum* is usually smooth and in some species (*L. linearifolium*) it is in addition somewhat pitted. Other species have somewhat rugose surface, but no ridges forming a net have ever been observed on the nutlets of this genus. This difference between the living *Lithospermum* and the fossil species *rugosa* was also emphasized by Miss Brooks (1929, p. 136). The nutlets of *Lithospermum* are, furthermore, fairly symmetrical about a plane which divides them into two equal halves, while the fossil nutlets are asymmetrical, and right and left individuals can be recognized among them. Finally, nutlets of *Lithospermum* have somewhat different construction of scars of attachment, which are flat (in rugose *L. arvense*) or, when elevated and concave (in *L. linearifolium* and others), do not develop wide ring and retain a flat bottom. No elaiosome of any prominence can be detected on these living nutlets. Contrary to this, nutlets of *rugosa* have a prominent elaiosome in the center of the double ring of the scar.

The writer can agree with Miss Brooks that the outer sculpture of the fossil nutlets in question makes them unlike the nutlets of *Lithospermum;* nevertheless he does not consider it possible to classify them with the living *Celtis* stones, in spite of the general resemblance of the netlike rugose character of the exterior.

The stones of *Celtis* have a very simple scar of attachment which is a mere small pit on the end opposite the somewhat cuspidate apex. The scar of *B. rugosa,* to the contrary, is very complicate, as described below. This important difference in the construction of the scar alone does not permit classification of the fossil fruits in question with *Celtis.* Besides the stones of all living and extinct species of *Celtis* known to the writer are fairly symmetrical about a plane that connects the apex and the scar, and, therefore, no right or left individual can be recognized among these stones. There is another important morphologic difference between the fruits in question, and this is the position of an opening which leads inside of them. The nutlets of *B. rugosa* have a canal at the ventral side of the scar of attachment, while the stones of both living and fossil *Celtis* have a canal at the cuspidate apex, but none at the scar.

In order to elaborate the comparison of the fossil fruits with their living relatives the writer secured a collection of fruits of the living European species of Borraginoidea-Anchusea group through the courteous help of Eleanor M. Reid, Emma E. Syrrine and H. C.

Skeels, and he also consulted the main literature on these living forms. All American species of the Borrage family which in some way resemble the fossil fruits in question were also comparatively studied. The following is a detailed description of the fossil nutlets and their comparison with some existing plants, among which their nearest living relatives must be sought.

Fossilized nutlets 2 to 3 mm. in length and 1.75 to 2.5 mm. in width, asymmetrically inflated, the dorsal side being much more convex than the ventral. On the ventral side (Pl. XXIX, Fig. 2*a*) a keel extends from a cuspidate apex nearly or quite to the scar of attachment. The keel is continued over the apex on the dorsal side (Pl. XXIX, Figs. 2*b* and 2*c*), but here it turns either to right or to left and makes a lateral connection with the scar of attachment, unless lost on the way. This, together with a moderate transverse twist (Pl. XXIX, Fig. 2*d*) of the whole nutlet, spoils its apparent bilateral symmetry. According to the right or left turn of the keel, which is accompanied by a corresponding twist, right and left nutlets can be recognized. The figured nutlet (Pl. XXIX, Figs. 2*a, b, c, d*) is a right one, and so are the nutlets of figure 8 and probably of figure 7, plate 1, of Berry's paper. The nutlet in the right upper corner of figure 1, plate XVII, of Brooks' paper is a right one, while the lower central nutlet of the same figure is a left individual.

The writer observed about an equal number of right and left nutlets in his extensive collections.

The surface of the nutlets is rugose. They are covered with narrow and, when perfectly preserved, much elevated ridges forming an irregular honeycomblike structure. The surface of the ridges and of the space between is shiny. The shiny areas between the ridges are somewhat knobby, and besides the writer observed on one of the best-preserved specimens a very fine cellular structure, which is shown on the photograph (Pl. XXIX, Fig. 7). A similar structure can be observed under magnification on the nutlets of the living *Anchusa*, *Lycopsis*, *Nonnea* and *Symphytum*, with which genera the fossil nutlets are compared by the writer (Pl. XXIX, Fig. 6). This cellular structure observable on the surface of the nutlets is a termination of prismatic structure of the shell of nutlets. In a fresh break of both living and fossil nutlets this prismatic or fibrous structure can be readily observed. There are about 40 fibers in a row per 1 mm. in *B. rugosa* and about 45 fibers in a row per 1 mm. in *Anchusa officinalis* and *A. capensis* nutlets.

The scar of attachment of *B. rugosa* is round and elevated, being

about as high above the surface of a nutlet as the ridges of the exterior. The diameter of the scar is nearly one-half of the shorter diameter of a nutlet. The scar consists of a double ring, inside of which is a prominent central elevation apparently corresponding to elaiosome of the living Borraginoideæ-Anchuseæ. The outer of the double ring is comparatively thin and has a smooth or slightly wavy edge. The inner ring is inserted, as if it were in a cone-in-cone position, into the outer ring of the scar. The edge of the inner ring is irregularly dentate, which may be explained as a disrupted tissue. A short and ventrally curved delicate pipe is ordinarily observed ventrally between the outer and inner rings of the scar. When this pipe is not preserved a corresponding thin canal leading inside of a nutlet can be seen. If the fossil nutlets have been arranged to form a fruit, in about the same fashion as the nutlets of their living relatives of the Borraginoideæ-Anchuseæ group do, the crooked pipes must have occupied a central position in the fruit and were turned from the bottom up (see sketch, Pl. XXIX, Fig. 3). If this reconstruction is correct, the pipes must represent basal portions of styles, one style for each ovule. These styles might or might not have been united in the middle of the flower.

The nutlets are hollow, the thickness of the walls exclusive of the ridges being about .08 mm. The ridges when well preserved are about .1 mm. high above the interspaces, but usually they are less prominent. The nutlets seem to be made of silica and are comparatively strong. Due to this fact complete nuts are rather common and usually they do not break on being separated from the inclosing rock. Mrs. Reid writes: "I think you are quite right in putting this species [*rugosa*] into the subsection Borraginoideæ-Anchuseæ, because of its evident mode of germination, as well as the character of its sculpture. In this section the flat adjacent faces of the nutlets form the germination valves, which are rimmed round by a raised edge. If you will sow a seedman's packet of *Anchusa* you will see them germinate . . . the flat face opening like a little door." [36] This flat face of a nutlet is that seen on figure 2*b* (*Biorbia rugosa*) and on figure 5*b*, plate XXIX. Among several hundreds of specimens of the fossil *Biorbia* in the writer's collection he observed one nutlet with a cracked-off flat face in a fashion as described by Mrs. Reid for germinating nutlets of *Anchusa*. All the other numerous nutlets of *Biorbia* do not show any traces of splitting in this or any other fashion, which apparently indicates that for some reason

36. From a personal letter to the writer of February 16, 1931.

(probably on account of lack of moisture) they never started to germinate at all.

The outer sculpture of the fossil nutlets is occasionally more or less obliterated as is likewise the scar of attachment. The cuspidate apex in such cases is also more or less rounded. Berry writes that this variation in sculpture of the nutlets which he studied "is not due to abrasion before or after fossilization . . . since it would have been equally effective on the apical point or the delicate rim of the hilum,[37] which is not the case." [38]

It seems possible that some nutlets could have been originally smoother than the others. Some living species of the borrage family, for instance *Cryptantha crassisepala,* have heterogeneous nutlets, one smooth and three rugose nutlets constituting a four-nutlet fruit. Other species of the family have mature nutlets commonly covered with papillæ, but sometimes they retain their smoothness at maturity.[39]

The peculiar honeycomblike outer sculpture of the fossil nutlets is one of their most characteristic features. Among the living representatives of the Borrage family *Anchusa, Lycopsis, Nonnea* and some species of *Symphytum* of Borraginoideæ-Anchuseæ and *Echinospermum greenei* Gray (probably of Borraginoideæ-Eritrichieæ) seem to be the only forms which have a similar sculpture of nutlets. However, the nutlets of American *Echinospermum greenei* are provided with prominent prickles, one at each knot of the honeycomb net of ridges, while no traces of such prickles can be detected on the best-preserved fossil nutlets. *E. greenei* has furthermore an entirely different scar of attachment, which is in form of a split along the ventral edge of a nutlet. Finally these living nutlets are fairly symmetrical about a plane and no right and left nutlets can be recognized. The nutlets of the living native European and Mediterranean species of *Anchusa, Lycopsis, Nonnea* and *Symphytum* possess not only a honeycomblike sculpture of nutlets, comparable to that of *Biorbia rugosa,* but they have also the same type of scar of attachment, which is somewhat asymmetrically (ventrally) located, and is provided with a prominent ring and an elaiosome. The asymmetry of these living nutlets is also of the same type as is observed on the fossil nutlets, and right and left nutlets can be easily recognized. On plate XXIX, figures 5*a* 5*b* and 5*c,* different views of a

37. Scar of attachment, as interpreted by the writer.
38. Berry, 1928, p. 1.
39. Gray, 1885, p. 275.

right nutlet of *Anchusa officinalis* Linneus are shown. Plate XXIX, figure 4, shows the arrangement of these nutlets to form a complete four-nutlet fruit, which consists of two right and two left nutlets alternately spaced around the center.

In spite of the above outlined similarity of the nutlets of *Anchusa, Lycopsis, Nonnea* and *Symphytum* to the fossil nutlets in question, the latter cannot be referred to any of these four living genera on account of the following differences:

1. The scar of attachment of the fossil nutlets is provided with a double ring while all the above-named living forms have a single ring.

2. The fossil nutlets have a ventral canal at the scar, a feature not observable on the nutlets of *Anchusa, Lycopsis, Nonnea* or *Symphytum.*

It is interesting that a ventral canal between the elaiosome and the ring of the scar is indicated on a sketch of a nutlet of *Pulmonaria officinalis,*[40] but *Pulmonaria* differs from *B. rugosa* in having nutlets perfectly smooth and shiny, or smooth and covered with short hairs. Furthermore, the nutlets of this living genus of Borraginoideæ-Anchuseæ are perfectly symmetrical about a central plane and among them no right and left nutlets can be recognized; their scar consists of only one ring.

All in all, it appears as if the fossil nutlets combine various features observable on the nutlets of *Anchusa, Lycopsis, Nonnea, Symphytum* and *Pulmonaria,* and besides have a special feature of their own—a double ring of the scar. On account of this they are given a new generic name, *Biorbia.*

The Borrage family is widely distributed throughout the temperate and tropical parts of the world, the species of *Anchusa, Lycopsis, Nonnea, Symphytum, Pulmonaria* and allied genera being exclusive European and Mediterranean forms.

OCCURRENCE OF FOSSIL FRUITS. Next to *Celtis* stones this is the most common species among fruits from the Ogallala beds in Kansas and Colorado. The writer collected nutlets of the species wherever the other herbaceous species have been found. It was not found by him, however, in the basal and topmost portions of Ogallala, where *Celtis* stones alone were collected.

40. Hegy, Illustrated flora von mittel Europe, 5 Band, 3 Teil, Fig. 3155, on page 2218.

Subfamily BORRAGINOIDEÆ-ERITRICHIEÆ Gürke.

Genus *Krynitzkia* Fisher and Meyer.

Krynitzkia (Cryptantha) coroniformis Elias n. sp.

(Pl. XXX, Figs. 1*a*, 1*b*, 1*c* and 1*d*.)

Only nutlets known. They are erect, ovate with acute apex, 1.5 longer than wide, rounded on the back and on the margins; coroniform in appearance from below, hence the specific name; apparently attached laterally to receptacle; the scar of attachment broad and trilobate at the base, passing into a gradually narrowing groove toward the apex. Some specimens have the back and sides covered with prominent prickles, while others are perfectly smooth and shiny. In the locality at Beecher Island, Colo., the smooth specimens outnumber considerably the tuberculate ones, while in the volcanic ash of Norton county, Kansas, only tuberculate nutlets occur. The presence or absence of tubercles seems to be the only difference between the two kinds of nutlets. There seems to be no objection to referring both smooth and tuberculate nutlets to one species; as Gray observes, some species of the borrage family, though commonly tuberculate, sometimes retain their smoothness in maturity.[41] The size of the nutlets is quite uniform, the length being about 2 mm. and the width slightly less than 1.5 mm.

The nutlets are hollow and are composed of calcium carbonate, the thickness of the walls in prickled nutlets being 0.035 to 0.075 mm. without prickles and to 0.13 mm. with prickles. The thickness of the walls in smooth nutlets is up to 0.12 mm.

The fossil nutlets resemble slightly the fruits of *Cynoglossum*, but they are several times smaller and their mode of attachment is different. The fruits of living *Oreocarya* are of the same magnitude as the fossil nutlets and have a similar scar of attachment. They differ, however, from the fossil form in having acute or winged margins. The living species of *Cryptantha* resemble the fossil form the most, and the nutlets of *Cryptantha crassisepala* (T. & G.) Greene are nearly identical with the fossil nutlets, except for their smaller size (Pl. XXX, Figs. 3*a*, 3*b*). They have obtuse margins and are coroniform from below; their scar of attachment is the same, except for the prominent median lobe at the base of the fossil form, which is absent in the living species. The latter has hetero-

41. Gray, 1885, p. 275.

geneous nutlets, three nutlets of a fruit being always tuberculate while the fourth one is always smooth and slightly longer than the others. The tuberculate and smooth nutlets of the fossil form are equal in size.

The living species of *Cryptantha* are natives of North and South America, and are most common in the western United States.

OCCURRENCE OF FOSSIL NUTLETS. Found at Black Wolf creek, near Beecher Island, Yuma county, Colorado, near the base of a bluff, 12 to 15 feet above the base of the Ogallala. Fruits, mostly halves of nutlets, in scores of specimens in grit. A great number of prickled fruits are scattered in the volcanic ash one mile east of Norton, Kan., where they occur together with *Celtis* stones.

Krynitzkia (*Oreocarya*) *chaneyi* Elias n. sp.

(Pl. XXX, Figs. 4*a*, 4*b*, 4*c* and 4*d*.)

Only nutlets known. They are triangular-ovate in outline both from the back and above; the width is only slightly less than length, which is 2.5 mm.; round and tuberculate on the back; the sides smooth; margins winged, the wings being short and dentate; the scar of attachment broad and slightly trilobate at the base, rapidly narrowing into a groove which does not quite reach the apex. The nutlets are hollow but comparatively strong, the thickness of the walls being 0.075 mm. They consist of calcium carbonate.

The fossil species apparently belongs to the living subgenus *Oreocarya*, which has nutlets that are triangular and nearly as wide as high. No such nutlets are known to the writer among other genera of the Borraginaceæ. The fossil nutlets approach in size and shape the nutlets of *Oreocarya suffruticosa*, *O. virgata* and *O. glomerata* (Pl. XXX, Figs. 2*a*, 2*b*), but these are smooth or only wrinkled on the back and are not winged. Some other species of *Oreocarya* (*O. virginiensis*, *O. oblata* and others) have a tuberculate back, but their flanks are also tuberculate and they are not winged. The winged species among the living *Oreocarya* (*O. setosissima* and others) have very thin wings which form a membranaceous margin all over the nutlets and are not restricted to the flanks only, as is the case in the fossil nutlets. *O. chaneyi* differs from all living nutlets of Oreocarya also in being more inflated. The scar of attachment of the fossil species is typical for both *Oreocarya* and *Cryptantha*, but the other features, as discussed above, relate the

fossil form with *Oreocarya*.[42] The species is named after Dr. Ralph W. Chaney.

The living species of *Oreocarya* are natives of western North America, including Mexico.

OCCURRENCE OF FOSSIL NUTLETS. Found in about a dozen specimens in sandstone about 45 feet below the top of the Ogallala, on the south side of Goose creek, in Wallace county, Kansas, near the state line.

Krynitzkia auriculata Elias n. sp.

(Pl. XXX, Figs. 5*a*, 5*b*, 5*c* and 5*d*.)

The nutlets of this species resemble in some respects *Krynitzkia* (*Oreocarya*) *chaneyi*, while in some other respects they approach *Krynitzkia* (*Cryptantha*) *coroniformis*. In the whole they represent a sort of an intermediate stage between the other two fossil forms of *Krynitzkia*, as if being their hybrid.

The nutlets are subtriangular in shape, being viewed both from the sides and from the base, but the triangularity of the shape is not as sharp as in *O. chaneyi*, and the basal view approaches the coroniform shape of *K. (Cryptantha) coroniformis*. The back of *K. auriculata* is as densely covered with prickles as the back of *K. coroniformis*, but the flanks of the former nutlets are only irregularly rugose, approaching the smothness of the flanks of *O. chaneyi*. In the majority of the nutlets of *K. auriculata* there can be detected that the prickles at the edges between the back and the flanks tend to fuse together, creating an embryo of a wing or an ear (hence specific name *auriculata*). In this the *K. auriculata* nutlets exhibit again a feature that is intermediate between the wingless *K. coroniformis* and the winged *K. chaneyi*. The scar of attachment of *K. auriculata* is of the same general type as in the last two species.

OCCURRENCE OF FOSSIL NUTLETS. Found in scores of specimens in somewhat cemented grit about 90 feet below the top of the Ogallala in W. of sec. 4, T. 12 S., R. 42 W., Wallace county, Kansas. Near by in the same bed a few nutlets of *Biorbia rugosa* and numerous fruits of *Berriochloa glabra* have been found.

42. The species united by Greene in genus *Oreocarya* were included by A. Gray in the genus *Krynitzkia* Fischer and Meyer, with which also the species of *Cryptantha* were classified. Many botanists use the generic name *Krynitzkia* in the sense of Fischer and Meyer and Gray, although the name *Cryptantha* has priority over *Krynitzkia*. *Oreocarya* and *Cryptantha* are considered as subgenera of *Krynitzkia*.

Celtis willistoni (Cockerell) Berry.

(Pl. XXIX, Figs. 8*a*, 8*b* and 8*c*.)

1909. *Tithymalus willistoni,* Cockerell, Torreya, vol. 9, p. 119.
1914. *Tithymalus willistoni,* Cockerell, Torreya, vol. 14, p. 137, Fig. 2*c*.
?1914. *Tithymalus phenacodorum,* Cockerell, Torreya, vol. 14, p. 137, Figs. 2A, 2B.
1925. *Celtis besseyi,* Barbour, E. H., Nebraska State Museum, vol. 1, Bull. 8, p. 89, Fig. 48.
?1925. *Celtis hatcheri,* Chaney, Carnegie Institution Publ. 349, p. 54, Pl. 1, Fig. 8.
?1927. *Celtis barbouri,* Chaney, American Museum Novitates, No. 283, pp. 1-2, Figs. 1, 2.
1928. *Celtis willistoni,* Berry, American Museum Novitates, No. 298, pp. 1-5, Figs. 1-6.

Hackberry (*Celtis*) stones are not rare in the Tertiary and Pleistocene of North America and in some arenaceous rocks of late Tertiary of the Great Plains they are very common. Several species have been established by various authors on the ground of these fossil stones alone, but the features of specific distinction, as given in the descriptions, are not very definite and the noted differences may be explained as variation within a single species. The variability in size and in rugosity of *Celtis willistoni* stones was a subject of some research by Berry,[43] and the writer believes that only an extension of a similar quantitative research in the variation of the stones of the living species of *Celtis* may help us to establish some valid criterion for specific separation of fossil *Celtis* stones. The features which have been thus far offered for discrimination between the fossil stones are a slight difference in size, difference in rugosity or slight difference in design of the rugosity. They were found by the writer of but little, if any, help in his attempt of an impartial (not influenced by stratigraphical occurrence) comparison of the *Celtis* stones collected by him in the Ogallala of northwestern Kansas with the numerous species previously described. He, furthermore, found that his fossil stones are indistinguishable from the stones of *C. occidentalis,* which now grows in the same area where the fossil stones have been collected.

In view of all this the writer is content at present that *Celtis* stones of his collections are referable to the earliest described fossil hackberry stones or *C. willistoni,* and provisionally he also concludes that *C. willistoni* stones belong to a hackberry closely related, if not identical, to living *C. occidentalis.*

The writer wishes to point out that among hundreds of specimens of *Celtis* stones which he collected in the Ogallala one can select specimens with very pronounced rugosity of the surface, and specimens which are nearly smooth. In two cases, furthermore, the writer

43. Berry, 1928, Am. Mus. Novitates, No. 298.

collected perfectly smooth and lustrous specimens which undoubtedly represent casts of the internal part of the same species of *Celtis*.

It is worth while to note here an interesting anatomical feature of *Celtis* stones to which little, if any, attention has previously been given, but which helps considerably in generic identification of these stones. This is the presence of a thin canal at the apex of hackberry stones. The canal is located slightly below the apex and is oblique to the surface of the stone (Pl. XXIX, Fig. 8*c*).

Occurrence. In numerous localities of Ogallala in northwestern Kansas and northeastern Colorado. Mostly in the middle portion of the formation, but occasionally also near the base and about at the top of it. Usually stones are scattered in a bed of grit or loam, but occasionally segregated to form irregular clusters.

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EXPLANATION OF PLATES.

PLATE XXVIII.

FIG. 1. Living *Panicum fasciculatum chartaginense* (Swartz) Doell. Fruit, dorsal view. From type specimen, after A. S. Hitchcock and Agnes Chase. Magnified about 12 times.

FIGS. 2*a*, 2*b*, 2*c*. Fossil *Panicum elegans* Elias n. sp. Protective cover of a fruit made of pale or palea, overlapped by fertile glume or lemma. Type specimen. Magnified about 12 times. 2*a*, Dorsal view of lemma. A. Three ridges at the apex corresponding to three principal veins of lemma. B. Lunal impression of embryo. Black spot in the lower part of lemma is an incidental break. 2*b*, Side view showing distally inflated palea on the right and overlapping lemma on the left. 2*c*, Ventral view showing palea inserted in lemma. C. Two keels or veins of palea. D. Scar of attachment of the fruit. E. Scar of fibrovascular bundle.

FIG. 3. Living *Panicum angustifolium* Ell. Microphotograph of middle portion of palea. Magnified 38 times.

FIG. 4. Fossil *Panicum elegans* Elias n. sp. Microphotograph of middle portion of palea. Magnified 44 times.

NOTE.—Black portions on the photograph of the living specimen figure 4 correspond to white portions of the fossil specimen figure 5, and *vice versa*. This difference is due to fossilization of protective cover, the transparent exterior of the glumes changing to semitransparent or nearly opaque.

FIGS. 5*a*, 5*b*. Fossil *Stipa kansasensis* Elias n. sp. Probably an upper portion of rolled palea with an apical extension into an awn (broken), accompanied by a twist (Fig. 5*b*). Note that the awn of living *Stipa* (Fig. 10) is pronouncedly twisted. 5*a* and 5*b* are different views of the same specimen, magnified 5 times.

FIGS. 6, 7, 8, 9. Fossil *Stipa kansasensis* Elias n. sp. Protective cover of fruit made of rolled lemma with a joint for awn at the apex. Awn broken away. Cotypes. Magnified 5 times. 6, Nearly complete lemma with hairy callus at the base. Lemma mostly exfoliated in the upper half, exposing internal cast made of sand cemented with calcium carbonate. Lower portion of lemma nearly bare of tubercles. 7, Large fruit with base broken off. Remains of lemma, tuberculate in upper half, smooth in lower half, surround internal cast made of sand. 8, Upper part of lemma covered with upright bristles at the joint and with tubercles below. Microphotograph 12 is made from this specimen. 9, Lower part of lemma.

FIG. 10. Living *Stipa neesiana* Trin. Sketch is made from a herbarium specimen. Magnified 2 times.

FIG. 11. Living *Stipa neesiana* Trin. Apical portion of lemma, showing bristles of the top and tubercles below with striations on the interspaces of the surface. Tubercles appear as black round spots, which is due to their transparency. The corresponding tubercles of the fossil fruits (Fig. 12) are opaque, which is due to fossilization. Thus they appear white and prominent on the photograph. Magnified 31 times.

FIG. 12. Fossil *Stipa kansasensis* Elias n. sp. Apical portion showing bristles at the top and tubercles below with striations on the interspaces of the surface. Cotype. Magnified 33 times.

FIGS. 13*a*, 13*b*, 13*c*. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Small-size fruit. Magnified 5 times. 13*a*, Ventral view of lemma with inclosed palea. 13*b*, Side view of lemma. A, Middle keel or vein. B, Basal portion of awn which is broken away. 13*c*, Basal view of lemma with inclosed palea. C, Scar of attachment. D, Lateral keels or veins.

FIG. 14. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Apparently pericarp of caryopsis, which was found inside of a protective cover. Portion to show anatomy. Black spots represent transparent tissue with less transparent ridges forming a net. Magnified 35 times.

FIG. 15. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Portion of lemma to show longitudinal striation. Magnified 32 times.

FIG. 16. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Portion of lemma to show irregular transverse sculpture. Magnified 32 times.

PLATE XXVIII.

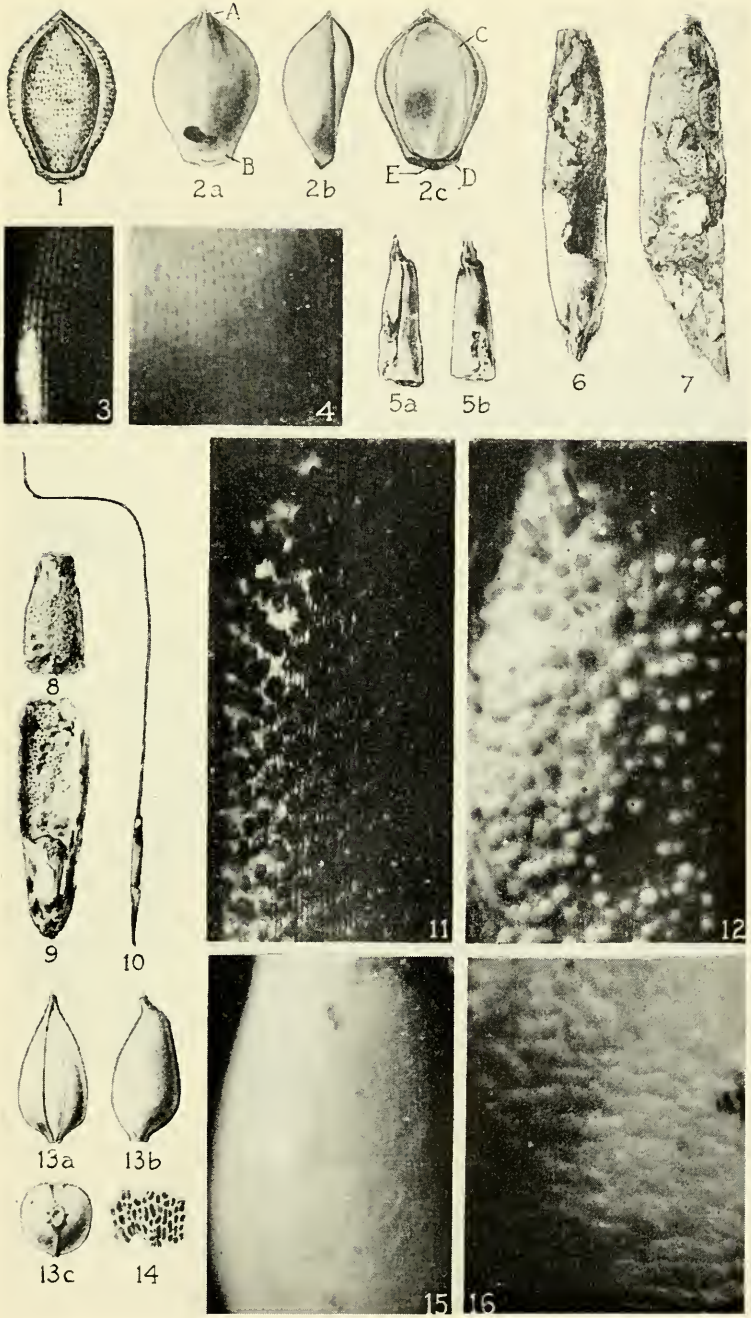


PLATE XXIX.

FIGS. 1*a*, 1*b*, 1*c*. Fossil *Berriochloa glabra* (Berry) Elias n. comb. Large-size fruit. Magnified 5 times. 1*a*, Side view of lemma. A, Middle keel or vein. B, Lateral veins. C, Basal portion of awn which is broken away. 1*b*, Ventral view of lemma with inclosed palea. D, Two ribs or veins of palea. 1c, Basal view. Note five ribs of lemma and two of palea.

FIGS. 2*a*, 2*b*, 2*c*, 2*d*. Fossil *Biorbia rugosa* (Berry) Elias n. comb. Right (in differentiation from left) nutlet. Magnified 10 times. 2*a*, Ventral view, 2*b*, Side view. 2*c*, Dorsal view. 2*d*, Basal view.

FIG. 3. Fossil *Biorbia rugosa* (Berry) Elias n. comb. Restoration of a fruit made of four nutlets. Side view. Magnified about 5 times.

FIG. 4. Living *Anchusa officinalis* Linneus. Four nutlets fruit. Top view. Specimen from Denmark, Botanical Gardens. Magnified 10 times.

FIGS. 5*a*, 5*b*, 5*c*. Living *Anchusa officinalis* Linneus. Left nutlet, from same locality. Magnified 10 times, 5*a*, Dorsal view. 5*b*, Side view. 5*c*, Ventral view.

FIG. 6. Living *Anchusa officinalis* Linneus. Microphotograph of the distal part of a nutlet. Magnified 35 times.

FIG. 7. Fossil *Biorbia rugosa* (Berry) Elias n. comb. Microphotograph to show fine tubular holes which are seen on somewhat exfoliated surface of a nutlet. Magnified 35 times.

FIGS. 8*a*, 8*b*, 8*c*. Fossil *Celtis willistoni* (Cockerell) Berry. 8*a*, Side view. 8*b*, Rear view (sculpture not shown). 8*c*, Internal view of apical portion of a stone. 8*a*, 8*b* magnified 5 times. 8*c* magnified 10 times.

PLATE XXIX.

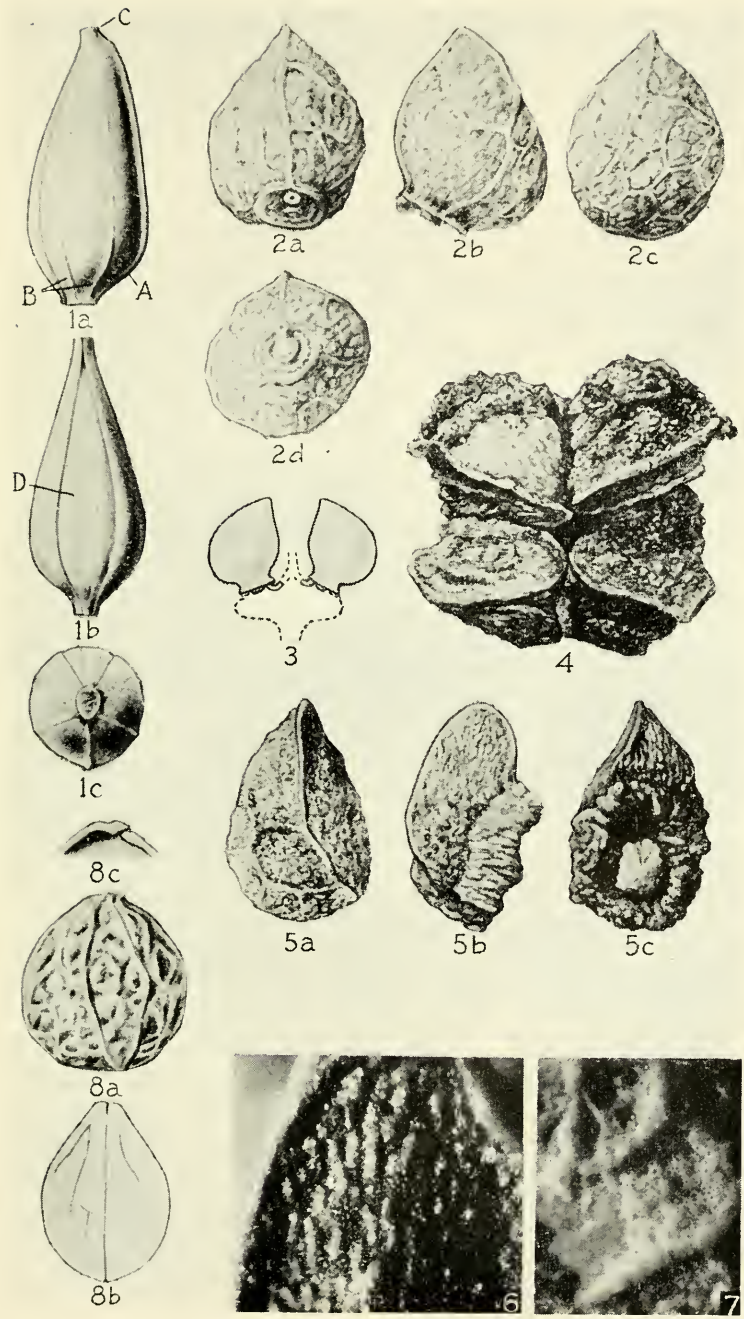


PLATE XXX.

FIGS. 1*a*, 1*b*, 1*c*, 1*d*. Fossil *Krynitzkia* (*Cryptantha*) *coroniformis* Elias n. sp. Nutlet. Type specimen. Magnified 10 times. 1*a*, Basal view. 1*b*, Dorsal view. 1*c*, Side view. 1*d*, Ventral view.

FIGS. 2*a*, 2*b*. Living *Krynitzkia* (*Oreocarya*) *glomerata* (Pursh) Green. Nutlet from Canon City, Colo. Magnified 10 times. 2*a*, Ventral view. 2*b*, Top view.

FIGS. 3*a*, 3*b*. Living *Krynitzkia* (*Cryptantha*) *crassisepala* (T. & G.) Green. Tuberculate nutlet from Wichita county, Kansas. Magnified 10 times. 3*a*, Basal view. 3*b*, Ventral view.

NOTE.—Vertical line to the right indicates comparative length of the smooth nutlet of the same fruit, to which the tuberculate nutlet belongs.

FIGS. 4*a*, 4*b*, 4*c*, 4*d*. Fossil *Krynitzkia* (*Oreocarya*) *chaneyi*. Elias n. sp. Nutlet. Magnified 10 times. 4*a*, Top view. 4*b*, Dorsal view. 4*c*, Side view. 4*d*, Ventral view.

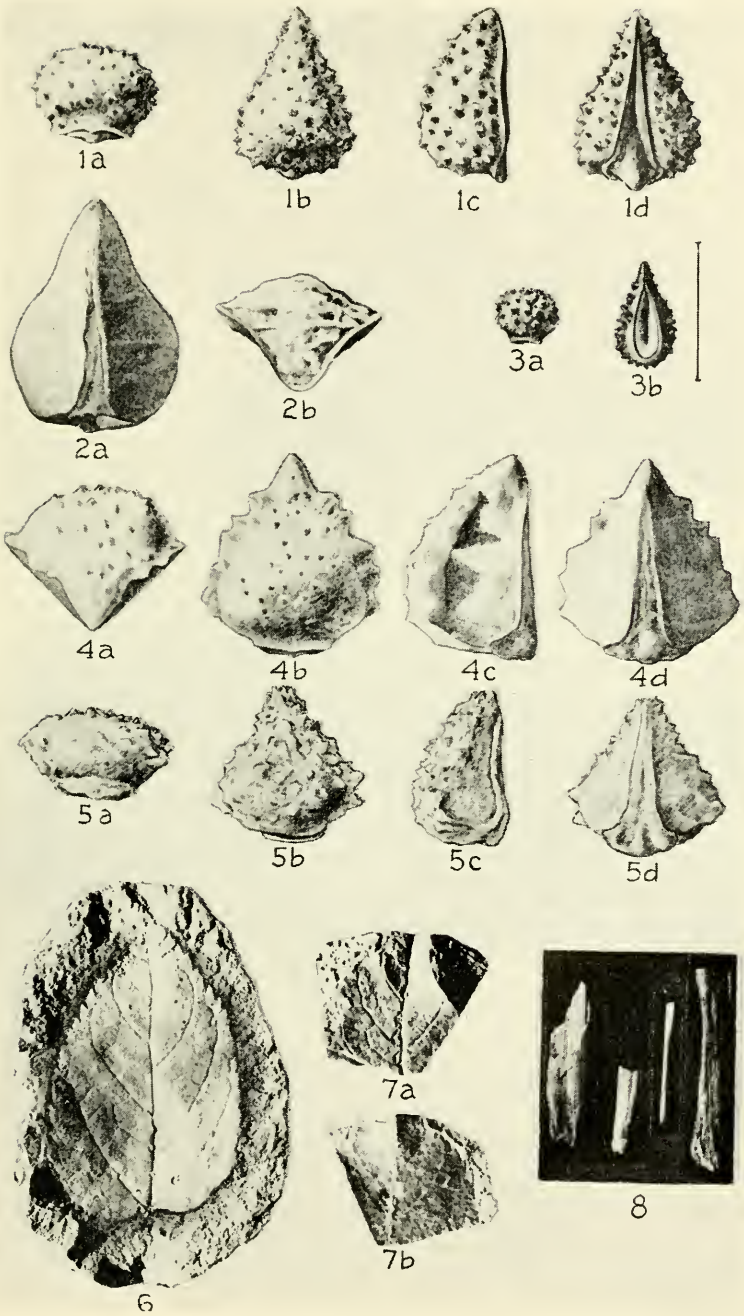
FIGS. 5*a*, 5*b*, 5*c*, 5*d*. Fossil *Krynitzkia auriculata* Elias n. sp. Nutlet. Magnified 10 times. 5*a*, Bottom view. 5*b*, Dorsal view, 5*c*, Side view. 5*d*, Ventral view.

FIG. 6. Fossil *Populus balsamoides* Goeppert. From the diatomaceous marl of Beaver county, Oklahoma. Natural size.

FIGS. 7*a*, 7*b*. Fossil *Populus* cf. *balsamoides* Goeppert. From the diatomaceous marl of Wallace county, Kansas. Natural size. 7*a* and 7*b* are positive and negative of the same fragmentary leaf. 7*a* shows nerves. 7*b* shows dentate edge of the leaf.

FIG. 8. Petrified stems (straw) of grasses. Natural size. From Ogallala formation, Kansas.

PLATE XXX.



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Pliocene Diatoms of Wallace County, Kansas.

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INTRODUCTION.

THROUGH the interest of Dr. Raymond C. Moore and Prof. M. K. Elias, of the State Geological Survey of Kansas, I have been enabled to study two samples of diatom-bearing marl from Wallace county. The samples are located more accurately as follows:

A. Diatom marl from center sec. 11, T. 11 S., R. 38 W., Marshall ranch, North Fork Smoky Hill river, Wallace county, Kansas; M. K. Elias, Coll.

B. Diatom marl from NW¼, sec. 29, T. 12 S., R. 41 W., about one-half mile east of the Collins ranch, Wallace county, Kansas; M. K. Elias, Coll.

The material is a snow-white, soft, chalky rock, of low specific gravity. In addition to extremely abundant fresh-water diatoms there is a large percentage of powdery calcium carbonate. Very little detrital matter is present in the samples submitted. The beds have been placed in the Ogallala formation which, in turn, is considered to be Lower Pliocene on evidence derived from mammalian fossils.

PREVIOUS LITERATURE.

There are very few published references to the living or fossil diatoms of Kansas. A fairly thorough search has revealed only the following:

A bibliography of the Diatomeceæ by Julien Deby, published in 1891, contains the following entry under F. Wolle: "Fourth contribution to the knowledge of Kansas Algæ. Bull. Washburn College, Lab. Nat. Hist. vol. 2, 1889, p. 64." I have not been able to consult this publication, but it probably contains some information relating to the diatoms of the state.

* Contribution from the State Geological Survey of Kansas.

In 1890 Wolle (Diat. N. America, 1890, Pl. 97, Figs. 1, 2, 5, 11) mentioned *Biddulphia lævis* Ehrenberg as an inhabitant of the salt marshes of Kansas, and on plate 103, figures 8, 9 and 10, he illustrated specimens of the same from Nebraska.

On March 12, 1931, the State Geological Survey of Kansas published anonymously its (mimeographed) Circular 3, entitled: "Diatomaceous Marl from Western Kansas, a possible source of hydraulic lime," pp. 1-5. This contains a detailed description of the localities in Wallace county from which the two samples herein studied were obtained. The paper also contains chemical analyses; suggestions of possible utility of the material; account of the discovery of the deposits by Professor Elias; discussion of the geologic age; and a bibliography. The latter contains the following seven titles, which have a bearing on deposits containing fossil diatoms in Kansas and neighboring states:

1. Adams, George. Note on a Tertiary Terrane new in Kansas Geology. Amer. Geol. vol. 29, 1902, p. 301.

2. Barbour, Erwin H. Diatomaceous deposits of Nebraska. Nebraska Acad. Sci. Publ. No. 7, 1896.

3. Barbour, Eleanor. Preliminary notice of a newly discovered bed of Miocene diatoms. Nebraska Geol. Surv. vol. 3, pt. 12, 1910.

4. Berry, E. W. Fossil plants from the late Tertiary of Oklahoma. Proc. U. S. Nat. Mus. vol. 54, 1917, p. 627.

5. Buttram, Frank. Volcanic dust in Oklahoma. Oklahoma Geol. Surv. Bull. 13, 1914.

6. Case, E. C. Geological reconnaissance in southwest Kansas and No Man's Land. Kansas Univ. Quart. vol. 2, 1894, p. 143.

7. Cragin, F. W. On a leaf-bearing terrane in the Loup Fork. Amer. Geol. vol. 18, 1891, pp. 29-32 (six species of diatoms listed as determined by F. Wolle).

The California Academy of Sciences contains a considerable number of collections of living material from various parts of the state. These were assembled about fifteen years ago by Edward C. Johnston, but they have not yet been cleaned or studied.

The diatoms of Nebraska have been examined in detail by Clarence J. Elmore[1] and his paper is the most important which has been published for the Mississippi valley area from a taxonomic standpoint.

He did not refer to any previous literature on the subject for the state. The species found in the fossil deposits known to him were incorporated, and these will need to be considered in any general survey of the diatomites of the region.

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1. Elmore, Clarence J. The Diatoms (Bacillarioideæ) of Nebraska. Nebraska University Studies, vol. 21, Nos. 1-4, Jan.-Oct., 1921, pp. 22-214, pls. 1-23 [860 figs.]. The paper also apparently forms vol. 8 of the Nebraska Geological Survey.

Many classical monographs have been consulted in the preparation of the present report, a few of which are listed under the individual species. In none of these did I find any records for Kansas and neighboring states.

A detailed description of the geology of Wallace county, Kansas, including the deposits from which the samples studied were obtained, has been published by Professor Elias.* This appeared after the present paper had been prepared and it should be consulted for further information.

ECOLOGY.

The two samples studied contain a large amount of calcium carbonate. Upon removal of this material, the residue consists almost exclusively of diatoms. In one of the samples (A) these fossils are almost perfectly preserved, but in the other the silica has weakened, as is often the case when in contact with alkaline waters. Under such conditions the individual organisms are usually somewhat corroded and break into fragments during the cleaning operations. Nevertheless, the species found in the two localities are almost identical and the same ones dominate both. The evidence furnished by the fossils indicates deposition in the same lake basin and during the same interval of time.

No really large diatoms were found in this material. No *Surirella, Campylodiscus* or *Pleurosigma* were discovered. The genus *Cymbella* is extremely abundant and may be considered dominant. This, together with the other forms found, furnishes convincing evidence that the deposits accumulated in a relatively shallow lake basin, the water of which would be called fresh. That is, it was neither saline, alkaline nor brackish. It is difficult to account for the presence of the large proportion of calcium carbonate under such circumstances, but it seems probable that at least a part of it was precipitated by such plants as *Chara,* and perhaps some other aquatic vegetation.

LIST OF SPECIES.

In the selection of names for the various species I have been guided by modern trends of diatom nomenclature. The late Charles S. Boyer's[2] Synopsis is especially valuable as a guide in this respect.

*Elias, Maxim K. The Geology of Wallace County, Kansas. State Geol. Surv. Kansas, Bull. 18, April 1, 1931 [copy received at Calif. Acad. Sci., April 30, 1932], pp. 1-254, 42 pls., 7 text figs. [See, especially, pp. 159-163, 209, 214-221.]

2. Boyer, Charles S. Synopsis of North America Diatomaceæ. Pt. 1, Proc. Acad. Nat. Sci. Philadelphia, vol. 78, 1926 [1927], Suppl. pp. 1-228. Pt. 2, Op. cit. vol. 79, 1927, Suppl. pp. 229-583.

The student of these organisms encounters much difficulty in the interpretation of the descriptions and figures of the older authors who labored with imperfect optical appliances. Arbitrary decisions have often been made in applying the old names and, fortunately, diatomatists are in almost universal agreement in such matters. The few sporadic attempts to apply certain rigid rules of nomenclature have met with a much-deserved and dismal failure.

In the preparation of the illustrations for this report no effort was expended in attempting to make all of the photographs to a predetermined scale of enlargement. Instead, sufficient magnification was employed in each case to display the essential structures as well as possible, due regard having been paid to loss of depth of focus with increased enlargement of the image. Each individual photographed was measured with a filar micrometer and this figure was divided into the major dimension of the finished print to secure the times enlargement recorded. These will be approximately correct in the printed plates, but some allowance should be made for errors of the lithographer. The final plates may be checked in critical cases. The procedure outlined and followed is believed to be more nearly accurate than the customary attempt to make illustrations to a given, even-number scale, such as: $\times 1000$. Such efforts are almost never exact, and they often deviate so far from truth as to be actually misleading.

The individual diatoms were selected from dry strewings and mounted on species-slides in hyrax under measured covers of uniform thickness. The photographs were necessarily made with oil immersion lenses and condenser and under conditions familiarly known as "critical microscopy."

All of the specimens mentioned have been deposited in the University of Kansas.

Amphora reinholdi Hanna, n. sp.

(PLATE XXXI, Figure 1.)

Valve lunate with slightly rostrate ends, ventral margin gently curved; central nodule not dilated; central zone with a band of about five coarsely punctate striæ; remainder of surface finely striate with rows of punctæ about half the size of those of the central zone. Length, .0472 mm.; width, .018 mm.

Holotype, No. 1 (K. U.) from sec. 11, T. 11 S., R. 38 W., Wallace county, Kansas; M. K. Elias, Col.

If this species has been previously described it is in some obscure

publication which was overlooked or it is concealed by unrecognizable drawing. It has very distinctive and what appear to be characteristic markings; these are best seen with immersion objectives.

The species is named for Dr. Th. Reinhold, of Haarlem, Holland, who has furnished me with numerous collections of European diatoms.

Amphora veneta Kützing.

(PLATE XXXI, Figure 2.)

Amphora veneta KÜTZING, Bacill., 1844, p. 108, pl. 3, fig. 25.—SCHMIDT, Atlas Diat., pl. 27, 1875, fig. 16.—VAN HEURCK, Syn. Diat. Belique, 1880, pl. 1, fig. 17.—WOLLE, Diat. N. America, 1890, pl. 3, figs. 12, 13.—MEISTER, Beit, Krypt.-Flora, Schweiz., vol. 4, 1912, p. 194, pl. 33, figs. 14, 15.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 345, fig. 631.

This is a very small species with exceedingly fine and delicate markings. The photograph shown herewith was taken with full 1.20 N. A. from a hyrax mount. The characters are not well shown in most illustrations, the one of Hustedt (1930) being the most satisfactory of any which was found. The species is very abundant in the finer washings of the Wallace county samples, and if care is not exercised in the cleaning most of them will be lost.

Anomoeoneis sphaerophora (Ehrenberg).

(Plate XXXI, Figures 3, 4.)

Navicula sculpta EHRENBERG, Abh. Akad. Wiss. Berlin, 1840, p. 16; [after CHASE].—EHRENBERG, Mikrog., 1854, pl. 10, I, fig. 5*a*, *b*; pl. 10, II, fig. 3; pl. 38 A, fig. 13.—SCHMIDT, Atlas Diat., pl. 49, 1877, figs. 46-48.—VAN HEURCK, Syn. Diat. Belgique, 1880, p. 100, pl. 12, fig. 1.—PANTOCSEK, Beit Kennt. Bacill. Ungarns, pt. 2, 1889, p. 53, pl. 11, fig. 191.—WOLLE, Diat. N. America, 1890, pl. 9, figs. 44, 45.—VAN HEURCK, Treat. Diat., 1896, p. 216, pl. 4, fig. 194.

Anomoeoneis sculpta (EHRENBERG), CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 27, 1895, p. 6.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 117, pl 17, fig. 8.—BOYER, Proc. Acad. Nat. Sci. Philadelphia, vol. 79, 1927, Suppl. p. 324.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 262, figs. 422-425 [as *A. sphærophora* and vars. *sculpta, guntheri* and *polygramma*].

Navicula rostrata EHRENBERG, Ber. Akad. Wiss. Berlin, 1840, p. 213.—KÜTZING, Bacil. 1844, p. 94, pl. 3, fig. 55.—RABENHORST, Süsswass. Diat., 1853, p. 37, pl. 6, fig. 52.—DONKIN, Brit. Diat., 1871, p. 15, pl. 2, fig. 9.

Navicula tumens W. SMITH, Syn. Brit. Diat., vol. 1, 1853, p. 52, pl. 17, fig. 150.

Navicula bohemica EHRENBERG, Mikrog., 1854, pl. 10, I, figs. 4 a, b.—EHRENBERG, Abh. Akad. Wiss. Berlin, 1870, pl. 1, I, fig. 2; pl. 2, I, fig. 34.—SCHMIDT, Atlas Diat., pl. 49, 1877, figs. 43-45.

Stauroneis polygramma EHRENBERG, Abh. Akad. Wiss. Berlin, 1841, [1843], p. 135, pl. 2, VI, fig. 30.—KÜTZING, Bacill. 1844, p. 106, pl. 29, fig. 7.—RABENHORST, Süssw. Diat., 1853, p. 48, pl. 9, fig. 18.

Navicula sphærophora KÜTZING, Alg. exsicc. 1830-1836, Dek. 84 (according to O. MÜLLER), —EHRENBERG, Abh. Akad. Wiss. Berlin, 1841 [1843], p. 419, pl. 3, IV, fig. 3.—KÜTZING, Bacill. 1844, p. 95, pl. 4, fig. 17.—RABENHORST, Süssw. Diat., 1853, p. 40, pl. 6, fig. 5.—W. SMITH, Syn. Brit. Diat., vol. 1, 1853, p. 52, pl. 17, fig. 148.—GRUNOW, Verh. k. k. Zoöl. Bot. Ges. Wien, vol. 10, 1860, p. 540, pl. 2, fig. 34.—DONKIN, Brit. Diat., 1871, p. 34, pl. 5,

fig. 10.—SCHMIDT, Atlas Diat., pl. 49, 1877, figs. 49-51.—BRUN, Diat. Alps, Jura, 1880, p. 67, pl. 7, fig. 16.—VAN HEURCK, Syn. Diat. Belgique, 1880, p. 101, pl. 12, figs. 2, 3, [as var. *minor*].—WOLLE, Diat. N. America, 1890, pl. 17, fig. 13.—VAN HEURCK, Treat. Diat., 1896, p. 216, pl. 4, fig. 195.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 87, pl. 11, figs. 398-400.

Anomoeoncis sphærophora (EHRENBERG), PFITZER, Unters. Bau u. Entwicklung, Bacill., in Hanstein, Bot. Abh. vol. 2, pt. 1, 1871, p. 77, pl. 3, fig. 10.—CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 27, 1895, p. 6.—MÜLLER, O., Hedwigia, vol. 38, 1899, pp. 295-305, 317, pl. 12, figs. 1-15, [numerous vars.].—SCHÖNFELDT, Diat. Germaniae, 1907, p. 153, pl. 9, fig. 164.—MIGULA, Krypt.-Flora, vol. 2, 1907, p. 268, pl. 7 K, fig. 8.—HUSTEDT, Süssw. Diat. Deutschlands, 1909, p. 37, pl. 7, fig. 3.—OSTRUP, Danske, Diat., 1910, p. 70, pl. 4, fig. 195.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 117, pl. 17, fig. 7.—MAYER, Ber. Naturwiss. ver. Regensburg, vol. 14, 1912 [1913], p. 129, pl. 2, fig. 25.—BOYER, Diat. Philadelphia, 1916, p. 80, pl. 40, fig. 2.—BOYER, Proc. Acad. Nat. Sci. Philadelphia, vol. 79, Suppl. 1927, p. 324.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacil. (Diat.), 1930, p. 262, figs. 422-425 [with vars.].

Otto Müller has shown that there is no sound reason for specific separation of the numerous variants in the assemblage grouped about *A. sphærophora*. He did recognize several varieties by trinomial names from El Kab, in North Egypt, but I have not found such practice profitable in the use of diatoms for purposes of geologic correlation. It seems much better in such cases as this to recognize that we are dealing with a plastic organism capable of assuming innumerable minor variations and try to define the limits and average of the series. Unless a variation has some particular significance, geologic, biologic, evolutionary or otherwise, it is unworthy of a separate name. In the case of *sphærophora* it is well known that many of the named variations can usually be found in any place where the group is at all common.

The above synonymy contains merely a portion of the references and names. Müller grouped all of the following under the species, synonyms in italics:

Anomoeoneis sphærophora (Kützing) 1833-1836.

forma rostrata, n. f.
forma capitata genuina, n. f.
var. *biceps* Ehrenberg, 1843.
var. *minor* Grunow, 1860.
var. *subcapitata* Grunow, 1860.
var. elliptica, n. v.
  forma elongata, n. f.
  forma curta, n. f.
var. polygramma (Ehrenberg) 1843.
costata Kützing, 1844.
bohemica Ehrenberg, 1854.
fossilis Ehrenberg, 1854.
var. navicularis, n. v.
  forma elongata, n. f.
  forma curta, n. f.
var. güntheri, n. v.
  forma truncata n. f.
var. sculpta Ehrenberg, 1854.
  rostrata Kützing, 1844.
  tumens W. Smith, 1853.
  pannonica Grunow, 1860.
  trigramma Fresenius, 1862.

Choosing the proper name for the species must be somewhat arbitrary, and there is sufficient precedent for the adoption of *sphærophora* over any of the others. Such procedure has guided diatomists in the past rather than rules of strict priority, and it is certain that their nomenclature is in no greater confusion than is that of groups

which have been legislated out of interest. It is particularly fortunate that usage has been the guide in this study because there is scarcely an early named species which was sufficiently well illustrated to meet the needs of modern microscopists. The reason for this lies in the inadequacy of the optical appliances then available. To attempt to interpret strict priority would necessarily lead to endless controversy and confusion.

Therefore, *sphærophora* is here adopted, although it is doubtful if it is the first name assigned to a member of the group of variants. Müller cited "Kützing, 1833-1836, Dek. nr· 84." This means that Kützing used the name in a series of preparations in those years, and which are usually cited "Alg. exsicc." or "Algar. æquæ dulcis Germanicæ, Decades 1-84-." Probably this would not constitute publication in the usual interpretation of the term. If not, Ehrenberg should be cited as author of the name because he used it in 1843, a year before Kützing actually published it. Other names which have precedence are *sculpta, rostrata* and *polygramma,* but no useful purpose would be served in an attempt to revive any of them even if it could be proven that they are completely applicable.

I have outlined the history of this species in some detail for several reasons. It appears to be an important one in the deciphering of the sequence of fresh-water deposits in western North America. It will serve as an example of the really great amount of literature which pertains to most of our common fresh-water diatoms.

The species is very common in sample B, but is rare in A, of the Wallace county, Kansas, material. At the present time it is a definite indicator of more or less saline waters and is common in such lakes as Pyramid, in Nevada. I do not believe that this has always been its habitat, because its other associates in sample B practically prove that the water in which they lived was fresh. It is entirely conceivable that such a species may well have been an inhabitant of fresh waters during the Pliocene and only very recently developed the saline habitat.

Cocconeis placentula Ehrenberg.

(Plate XXXI, Figures 7, 8.)

Cocconeis placentula EHRENBERG, Infus. 1838, p. 184.—EHRENBERG, Abh. Akad. Wiss. Berlin, 1841 [1843], pl. 1, I, figs. 10, 24.—KÜTZING, Bacill. 1844, p. 73, pl. 28, fig. 13.—W. SMITH, Syn. Brit. Diat., vol. 1, 1853, p. 21, pl. 3, fig. 32.—VAN HEURCK, Syn. Diat. Belgique, 1880, p. 133, pl. 30, figs. 26, 27.—WOLLE, Diat. N. America, 1890, pl. 33, figs. 17, 18; [poor figures].—SCHMIDT, Atlas Diat. pl. 192, 1894, figs. 38-51.—CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 27, no. 3, 1895, p. 169.—SCHÖNFELDT, Diat. Germaniae, 1907, p. 123, pl. 8, fig. 232.—HUSTEDT, Süssw. Diat. Deutschlands, 1909, p. 27, pl. 5, fig. 19.—MEISTER, Beit.

Kryptogamenflora, Schweiz, vol. 4, 1912, p. 93, pl. 12, figs. 6-10; [with vars.].—MAYER, Ber. Naturw. Ver. Regensburg, vol. 14, 1912 [1913], p. 83, pl. 5, figs. 17-23, 25-27, pl. 13, figs. 28, 29.—BOYER, Diat. Philadelphia 1916, p. 57, pl. 16, figs. 19, 20, [var. *lineata*, pl. 16, fig. 29].—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 101, pl. 13, figs. 500-504.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.) ,1930, p. 189, figs. 260-263; [with vars.].

The surface markings under low magnification or poor resolution are arranged in the form of irregular wavy lines, approximately parallel to the long axis. The heavy submarginal line in the raphe-bearing valve is the chief distinguishing character. The species is widespread at the present time and is common in many fresh-water fossil deposits as it is in those of Wallace county, Kansas. The form *lineata* is often recorded separately, but it is doubtful if it possesses any really important differentiating features.

Cyclotella kansasensis Hanna, n. sp.

(Plate XXXI, Figure 6.)

Valve circular, almost flat, central area slightly convex; outer zone marked by heavy, widely spaced radial bars; central area with heavy, irregularly scattered beads. Diam. .0141 mm.

Holotype, No. 6 (K. U.) from sec. 11, T. 11 S., R. 38 W., Wallace county, Kansas; M. K. Elias, Coll.

About 150 names, binomial, trinomial and quadrinomial have been applied to diatoms belonging to *Cyclotella*, yet a careful check of the literature has failed to disclose one to which these minute Kansas forms can be referred. It is true that many of the older names and some of the modern are represented by such small and generalized figures that they can never be certainly determined, and it is possible that some one or more of them may have been applied to the present form. Rather than assume such to be the case without reasonable assurance of correctness, it seems best to provide a new name with an adequate illustration, although this is done reluctantly. The species is extremely small but beautifully and fairly constantly sculptured. The central beaded zone possesses no geometric pattern.

Cymatopleura solea (Brebisson).

(Plate XXXII, Figure 3.)

Surirella solea BREBISSON, in BREBISSON & GODEY, Consid. Diat., 1838, p. 17.—KÜTZING, Bacill., 1844, p. 60, pl. 3, fig. 61.

Navicula librile EHRENBERG, Abh. Akad. Wiss. Berlin, 1831 [1833], p. 81.—EHRENBERG, Infus. 1838, p. 185, pl. 13, fig. 22.

Sphinctocystis librilis (EHRENBERG), HASSALL, Hist. Brit. Alg. vol. 1, 1845, p. 436, pl. 102, fig. 3.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 146, pl. 20, figs. 779-784.

Sphinctocystis librile (EHRENBERG), MANN, Cont. U. S. Nat. Herb. vol. 10, pt. 5, 1907, p. 382.

Cymatopleura solea (BREBISSON), W. SMITH, Ann. Mag. Nat. Hist. ser. 2, vol. 7, 1851, p. 12, pl. 3, figs. 8, 9.—W. SMITH, Syn. Brit. Diat., vol. 1, 1853, p. 36, pl. 10, fig. 78.—BRUN, Diat. Alps, Jura, 1880, p 97, pl. 1, fig. 10.—VAN HEURCK, Syn. Diat. Belgique, 1881, pl. 55, figs. 5-7.—WOLLE, Diat. N. America, 1890, pl. 60, fig. 1-4, 13.—VAN HEURCK, Treat. Diat. 1896, p. 367, pl. 12, fig. 482*b*.—MÜLLER, in SCHMIDT, Atlas Diat. pl. 245, 1904, figs. 1-4, 10, [with vars.].—SCHÖNFELDT, Diat. Germaniæ, 1907, p. 229, pl. 15, fig. 292; pl. 16, fig. 293.—HUSTEDT, in SCHMIDT, Atlas Diat. pl. 275, 1911, figs. 2-13 [with vars.].—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 216, pl. 38, figs. 16-19; pl. 39, figs. 1-4 [with 8 vars.].—BOYER, Diat. Philadelphia, 1916, p. 129, pl. 34, figs. 8, 9.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 425, fig. 823.

The above is a very small portion of the extensive literature pertaining to this species which might be cited. However, it is believed that it will provide some references which are accessible to most students. It further shows the futility of attempting to apply arbitrary rules of priority in the Diatomaceæ. So much uncertainty pertains to much of the early work on the group that common usage and interpretation must be taken into consideration in making a choice. Possibly neither the genus nor species-name here used was the first to be applied to the diatom, but there is plenty of precedent for its adoption over the earlier ones about which there is more or less doubt. The species is very rare in the Wallace county samples and a perfect specimen could not be found for illustration. The dark bar in the center of the photograph taken is foreign to the diatom, but it adhered so tenaciously that it could not be removed with the mechanical finger.

Cymbella aspera (Ehrenberg).

(Plate XXXI, Figure 9.)

Cocconema asperum EHRENBERG, Ber. Akad. Wiss. Berlin, 1839, pp. 30, 31; 1840, p. 206.—EHRENBERG, Mikrog. 1854, pl. 5, V, fig. 1; pl. 2, II, fig.21; pl. 14, fig. 81.

Cymbella aspera (EHRENBERG), CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 26, No. 2, 1894, p. 175.—SCHÖNFELDT, Diat. Germaniæ, 1907, p. 200, pl. 9, fig. 136.—HUSTEDT, Süsswass. Diat. Deutschlands, 1909, p. 55, pl. 7, fig. 2.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, p. 179, pl. 30, fig. 3—BOYER, Diat. Philadelphia, 1916, p. 61, pl. 18, fig. 1.—BOYER, Proc. Acad. Nat. Sci Philadelphia, vol 79, 1927 Suppl. p. 278.—HUSTEDT, Süsswass.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 365, fig. 680.

Frustulia gastroides KÜTZING, Linnaea, vol. 8, 1834 (Sep.), p. 15, fig. 9.

Cymbella gastroides (KÜTZING), Bacil., 1844, p. 79, pl. 6, fig. 4*b*.—RABENHORST, Süssw.-Diat., 1853, p. 21, pl. 7, fig. 2.—SCHMIDT, Atlas, Diat., pl. 9, 1875, figs. 1, 2, pl. 10, fig. 7. —VAN HEURCK, Syn. Diat. Belgique, 1880, p. 63, pl. 2, fig. 8.—WOLLE, Diat. N. America, 1890, pl. 7, figs. 4, 5, 12, 13.—MAYER, Ber. Naturw. Ver. Regensburg, vol. 14, 1912 [1913], p. 260, pl. 12, figs. 7, 13; pl. 13, fig. 20.—ELMORE, Univ Studies, Nebraska, vol. 21, 1921, p. 119, pl. 16, figs. 601-606.

It is extremely difficult to separate *C. aspera* from numerous other named forms, and it is probable that even though Cleve did considerable consolidating, much more is needed. The name *aspera* has

been more generally accepted in modern literature than *gastroides*, presumably because of the impossibility of definitely identifying Kützing's figures. Some authors recognized numerous "varieties" for some of the modifications, but I agree with Elmore that the procedure is not helpful in the classification of the members of the genus. Forms similar to the one photographed are very common in the two Wallace county, Kansas, samples.

Cymbella cesatii (Rabenhorst).

(Plate XXXIII, Figure 8.)

Navicula cesatii RABENHORST, Süssw. Diat., 1853, p. 30, pl. 6, fig. 89.—VAN HEURCK, Syn. Diat. Belgique, 1880, p. 88, pl. 8, fig. 35.—VAN HEURCK, Treat. Diat., 1896, p. 140, pl. 3, fig. 143.

Cymbella cesatii (RABENHORST), GRUNOW in SCHMIDT, Atlas Diat., 1881, pl. 71, figs. 48, 49.—CLEVE, Kongl. Sven. Vet. Akad. Handl. vol. 26, 1894, p. 160.—BOYER, Proc. Acad. Nat. Sci. Philadelphia, vol. 79, 1927 Suppl. p. 282.

This is one of the most abundant diatoms in the Wallace county samples. It is so nearly symmetrical that there need be no surprise that it has been called "*Navicula*"; presumably the characters of the terminal fissures are determining features. The transverse striæ are very lightly beaded. The species is usually rare and has not often been reported. The shape and size are similar to the form called *Navicula pauper* herein, but that species has more decidedly punctate striæ, the ends are not so acute and the terminal fissures are decidedly different.

Cymbella lanceolata (Ehrenberg).

(Plate XXXII, Figure 1.)

Cocconema lanceolata EHRENBERG, Infus. 1838, p. 224, pl. 19, fig. 6.—W. SMITH, Syn. Brit. Diat., vol. 1, 1853, pl. 23, fig. 219.—SCHMIDT, Atlas Diat., 1875, pl. 10, figs. 8-10.

Cymbella lanceolata (EHRENBERG), VAN HEURCK, Syn. Diat. Belgique, 1880, p. 63, pl. 2, fig. 7.—CLEVE, Kongl. Sven. Vet. Akad. Handl. vol. 26, no. 2, 1894, p. 174.—HUSTEDT, Süssw. Diat. Deutschlands, 1909, p. 55, pl. 7, fig. 1.—MEISTER, Beit.-Flora, Schweiz, vol. 4, 1912, p. 181, pl. 31, fig. 1.—MAYER, Ber. Naturwiss. Ver. Regensburg, vol. 14, 1912 [1913], p. 259, pl. 12, figs. 3-5, pl. 13, fig. 19.—BOYER, Diat. Philadelphia, 1916, p. 62, pl. 18, fig. 4.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 119, pl. 16, figs. 607-610; pl. 23, fig. 856.

This seems to be the most common diatom in both of the Wallace county, Kansas, samples. The species has a more convex ventral margin and is narrower in the center than *C. aspera* which is often called *gastroides* in the literature.

Cymbella mexicana (Ehrenberg).

(Plate XXXII, Figure 4.)

Cocconema mexicanum EHRENBERG, Ber. Akad. Wiss. Berlin, 1844, p. 342.—EHRENBERG, Mikrog. 1854, pl. 33, VII, figs. 6, 7.—SCHMIDT, Atlas Diat., pl. 10, 1875, figs. 32, 33; pl. 71, 1881, fig. 82.—WOLLE, Diat. N. America, 1890, pl. 6, fig. 4.

Cymbella mexicana (EHRENBERG), CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 26, No. 2, 1894, p. 177.—BOYER, Diat. Philadelphia, 1916, p. 62, pl. 18, fig. 5.

Cymbella kamtschatica GRUNOW, in SCHMIDT, Atlas Diat., 1875, pl. 10, fig. 31.—WOLLE, Diat. N. America, 1890, pl. 7, fig. 11.

Cymbella gastroides KÜTZING, HANNA & GRANT, Journ. Paleo., vol. 3, No. 1, 1929, p. 92, pl. 12, fig. 3; Pliocene, Kettleman Hills, Cal.

This species is widely distributed in west American fossil deposits and is apparently living in some of the lakes and streams. It is one of the most abundant forms in the Wallace county, Kansas, samples. No other common species in the region has the conspicuous stigma on the central nodule.

Cymbella parva (W. Smith).

(Plate XXXI, Figure 5.)

Cocconema parvum W. SMITH, Syn. British Diat., vol. 1, 1853, p. 77, pl. 23, fig. 222.

Cymbella parva (W. SMITH), SCHMIDT, Atlas, Diat., pl. 10, 1875, figs. 14, 15.—VAN HEURCK, Syn. Diat. Belgique, 1880, pl. 2, fig. 14.—GRUNOW, Denkschr. Akad. Wiss. Wien, vol. 48, No. 2, 1884, p. 97, pl. 1, fig. 9.—SCHÖNFELDT, Diat. Germaniæ, 1907, p. 198, pl. 10, fig. 137.—HUSTEDT, Süssw. Diat. Deutschlands, 1909, p. 55, p'. 7, fig. 13.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 183, pl. 31, fig. 7.—MAYER, Ber. Naturwiss. Ver. Regensburg, vol. 14, 1912 [1913], p. 253, pl. 2, fig. 34, pl. 13, fig. 18.—BOYER, Diat. Philadelphia, 1916, p. 61, pl. 38, fig. 14.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 120, pl. 16, figs. 611, 612.—HUSTEDT, Süssw.-Flora Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 363, fig. 675.

This is one of the smaller species of *Cymbella*, but it is very common in the Wallace county, Kansas, samples. It is more constant in size and shape than many of the members of the genus, yet it is doubtful if in a large series it could always be distinguished from some others, especially *cistula* and *cymbiformis*. According to Cleve the most reliable means of separation is the absence in *parva* of a distinct bead (stigma) on one side of the central nodule.

Cymbella ventricosa (Kützing).

(Plate XXXII, Figure 2.)

Frustulia ventricosa KÜTZING, Linnaea, vol. 8, 1834 [separate], p. 11, fig. 7.

Cymbella ventricosa KÜTZING, Bacill., 1844, p. 80, pl. 6, fig. 16.—CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 26, No. 2, 1894, p. 168—SCHÖNFELDT, Diat. Germaniae, 1907, p. 202, pl. 10, fig. 144.—HUSTEDT, Süsswass. Diat. Deutschlands, 1909, p. 54, pl. 7, figs. 11, 12.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 190, pl. 33, figs. 1-4; [with 4 vars.].—MAYER, Ber. Naturwiss. Ver. Regensburg, vol. 14, 1912 [1913], p. 268-271, pl. 11, figs. 6-12; pl. 27, fig. 2; [with vars.].—BOYER, Diat. Philadelphia, 1912, p. 62, pl. 18, figs. 14, 22; pl. 38, fig. 16; pl. 40, fig. 8.—BOYER, Proc. Acad. Nat. Sci. Philadelphia, vol. 79, 1927

[suppl.], p. 285.—HUSTEDT, Süsswass.-Flora, Mt.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 359, fig. 661.

Encyonema ventricosum (KÜTZING), SCHMIDT, Atlas Diat., pl. 10, 1875, figs. 57, 58.—VAN HEURCK, Syn. Diat. Belgique, 1880, p. 65, pl. 3, figs. 14; pl. Suppl. A, fig. 3.—WOLLE, Diat. N. America, 1890, pl. 8, figs. 19, 20.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 123, pl. 17, figs. 628, 629.

Cleve (1894) united the following names with *ventricosa:*

Encyonema prostratum Kützing, 1844.
Encyonema caespitosum Kützing, 1849.
Encyonema auerswaldii Rabenhorst, 1853.
Cymbella maculata W. Smith, 1853.
Cymbella affinis semicircularis Lagerstedt, 1873.
Cocconema lunula Ehrenberg, 1843.
Cymbella silesiaca Bleisch, 1865.
Cymbella minuta Hilse, 1862.
Cymbella variabilis Wartmann, 1859.

The same author stated that he could find no constant differences for the separation of *Cymbella turgida* Gregory 1856, which, however, is usually held to be distinct. Several varieties have been named. It may be gathered from this that the species is very variable, a fact amply demonstrated by the abundant specimens in the two samples from Wallace county, Kansas. The variations chiefly involve obtuseness of apices, straightness of ventral margin and distance of raphe from ventral margin. The individual photographed is a representative of the average condition found.

Denticula elegans Kützing.

(Plate XXXII, Figures 5, 6.)

Denticula elegans KÜTZING, Bacill., 1844, p. 44, pl. 17, fig. 5.—RALFS in PRITCHARD, Hist. Infus. Ed. 4, 1861, p. 773, pl. 13, fig. 4.—BRUN, Diat. Alps and Jura, 1880, p. 114, pl. 3, fig. 37.—VAN HEURCK, Syn. Diat. Belgique, 1880-1885, pl. 49, figs. 14, 15.—VAN HEURCK, Treat. Diat. 1896, p. 351, pl. 31, fig. 860.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 59, pl. 5, fig. 3.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 46, pl. 2, figs. 40-43.—HUSTEDT, Süsswass.-Flora, Mit.-Europas, Heft 10, Bacil. (Diat.) 1930, p. 382, fig. 725.

The markings on this diatom are fairly coarse, about 17 transverse rows of dots in .01 mm. It is abundant in the Wallace county, Kansas, deposits.

Fragilaria pinnata (Ehrenberg).

(Plate XXXII, Figures 7-12.)

Staurosira pinnata EHRENBERG, Ber. Akad. Wiss. Berlin, 1841, p. 144.

Fragilaria pinnata (EHRENBERG), Abh. Akad. Wiss. Berlin, 1841 [1843], p. 127, pl. 1, III, fig. 9, pl. 3, VI, fig. 8; [also many figures in Mikrogeolgie 1854].—HUSTEDT, in SCHMIDT, Atlas Diat., pl. 298, 1913, figs. 47-74.—HUSTEDT, Süssw.-Flora, Mitt.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 142, figs. 141-143.

Odontidium mutabile W. SMITH, Syn. Brit. Diat., vol. 2, 1856, p. 17, pl. 34, fig. 290.—WOLLE, Diat. N. America, 1890, pl. 48, figs. 7-12.

Fragilaria mutabilis (W. SMITH), VAN HEURCK, Syn. Diat. Belgique, 1881, p. 157, pl. 45 figs. 9-16; [with vars.].—SCHÖNFELDT, Diat. Germaniæ, 1907, p. 102, pl. 5, fig. 38.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 68, pl. 6, fig. 14.—MAYER, Ber. Naturw. Ver, Regensburg, vol. 14, 1912 [1913], p. 43, pl. 15, figs. 23, 24; pl. 26, figs. 13, 14.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 52, pl. 2, fig. 85; pl. 22, fig. 817.

This exceedingly variable diatom is abundant in sample B and rare in sample A. The difference is probably due to the first having been somewhat closer to shore or fixed objects to which the filaments could become attached. An excellent conception of the great variability of the species can be obtained from Hustedt's long series of figures in Schmidt's Atlas.

Gomphonema acuminatum Ehrenberg.

(Plate XXXII, Figure 14.)

Gomphonema acuminatum EHRENBERG, Ber. Akad. Wiss. Berlin, 1836, p. 56; [CHASE].—EHRENBERG, Infus., 1838, p. 217, pl. 18, fig. 4.—KÜTZING, Bacil., 1844, p. 86, pl. 13, fig. 1 (7).—EHRENBERG, Mikrog, 1854, pl. 4, II, fig. 41; pl. 6, I, fig. 34; pl. 14, fig. 74 *a, b;* pl. 15 A, fig. 87 *a, b;* pl. 15 B, fig. 34 *b;* pl. 16, II, fig. 43; pl. 16, III, fig. 34; pl. 17, I, fig. 52; pl. 17, II, fig. 34; pl. 37, I, fig. 11, pl. 34, XII*b*, fig. 10 *a. c.*—BRUN, Diat. Alps and Jura, 1880, p. 39, pl. 6, fig. 4.—VAN HEURCK, Syn. Diat. Belgique, 1880-1885, p. 124, pl. 23, fig. 16.—SCHMIDT, Atlas Diat. pl. 72, 1882, fig. 10; pl. 239, 1902, figs. 1-4, 11, 14, 15; pl. 240, 1902, figs. 1-6.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 170, pl. 29, figs. 6-8; [with 6 vars.].—BOYER, Diat. Philadelphia, 1916, p. 71, pl. 19, fig. 7; [var. *coronata* Ehr.]—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 109, pl. 14, figs. 530-534; pl. 23, figs. 845, 847.

Although the literature of *G. acuminatum* shows great variation in shape, the species is remarkably constant in the Wallace county, Kansas, deposits. It is there not common, but a few individuals can usually be found on each strewn slide. No less than 20 varietal names had been added to the species up to 1895. Of these the Kansas fossils resemble the form *intermedia* Grunow (in Van Heurck, Syn. Diat. Belgique, 1880-1885, pl. 23, fig. 21) perhaps more closely than any of the others which have been figured, although they approach the form often called *coronata* Ehrenberg in many respects. The separation of such forms hardly seems necessary or advisable for paleontological purposes.

Gomphonema semiapertum Grunow.

(Plate XXXII, Figure 13.)

Gomphonema semiapertum GRUNOW, in VAN HUERCK, Syn. Diat. Belgique, 1880, pl. 24, fig. 42.—SCHMIDT, Atlas Diat. pl. 216, 1899, figs. 5-8.—WOLLE, Diat. N. America, 1890, pl. 27, fig. 16.—CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 26, 1894, p. 182.

Gomphonema heideni FRICKE, in SCHMIDT, Atlas Diat. pl. 248, 1904, figs. 29-33.

Gomphonema heideni sparsistriata FRICKE, in SCHMIDT, Atlas Diat. pl. 248, 1904, figs. 26-28.

Grunow's locality is given as "Shasta, California," which probably means some deposit in the Pit river valley in Shasta county.

Schmidt repeated Grunow's record and added "Washington county" [Oregon] and "Pit river," California. The original locality of *heideni* was given as "Jones valley, California"; this is probably an error for "Ione," a town on the east side of the Sacramento valley, in the vicinity of which there are several deposits of Pliocene fresh-water diatoms. The species is widely distributed in west American lake deposits. It is very well characterized by the blank space in the center of one side and is subject to considerable variation in size, shape and closeness of transverse rows of beads. The series illustrated by Fricke can be duplicated in the Wallace county, Kansas, deposit where it is extremely common.

Navicula gibbula Cleve.

(Plate XXXIV, Figure 5.)

Navicula gibbula CLEVE, Kongl. Sven. Vet. Akad. Handl. vol. 26, No. 2, 1894, p. 140, pl. 5, fig. 17.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), p. 285, fig. 477.

If my identification of specimens in the Wallace county samples be correct, a very unusual distribution is disclosed for this diatom. It was described from Spitzbergen and has been recorded from Beeren island, in the North Atlantic, and from a few places in Europe. It has apparently not heretofore been found in America. Doubt as to the determination of the species might very well be had if it were not for the fact that the specimens agree with the published figures better than is usual in *Navicula* and if it were not accompanied by so highly distinctive an arctic form as *Pinnularia divergentissima*. Very minor differences in shape are all that were noted. Doctor Hustedt's illustration is particularly close. The species is rare in samples studied.

Navicula pauper Mann.

(Plate XXXIII, Figures 7, 9.)

Navicula pauper MANN, U. S. Geol. Survey, Prof. Ppr. 140 A, 1926, p. 54, pl. 31, fig. 6.

A single specimen found in the Wallace county, Kansas, material seems to be referable to this species, which was described from a fossil deposit near Mica, Wash. Certain slight details are different, but it is not believed that these are sufficient for specific separation in view of the fact that Doctor Mann's material was noticeably poorly preserved. The species is also similar in structure to the abundant *Cymbella cesatii* in the same samples, but that form is somewhat wider, the ends are narrower and the terminal nodules are at the extreme ends. In *N. pauper* the terminal nodules are some-

what removed from the extreme ends and are separated by a beaded zone.

Navicula radiosa Kützing.

(Plate XXXIII, Figures 1, 2.)

Navicula radiosa KÜTZING, Bacill. 1844, p. 91, pl. 4, fig. 23.—SCHMIDT, Atlas Diat., pl. 47, 1876, figs. 50-52.—BRUN, Diat. Alps, Jura, 1880, p. 78, pl. 8, fig. 2.—VAN HEURCK, Syn. Diat. Belgique, 1880, p. 83, pl. 7, fig. 20: [fig. 19 as var. *acuta*].—WOLLE, Diat. N. America, 1890, pl. 21, figs. 6, 7.—VAN HEURCK, Treat. Diat., 1896, p. 180, pl. 3, fig. 112.—DIPPEL, Diat. der Rhein,-Mainebene, 1904, p. 42, figs. 79-81.—SCHÖENFELDT, Diat. Germaniæ, 1907, p. 158, pl. 11, fig. 175.—MIGULA, Krypt.-Flora, vol. 1, pt. 1, 1907, p. 259, pl. 7 J, fig. 12.—HUSTEDT, Süsswass. Diat. Deutschlands, 1909, p. 40, pl. 4, fig. 10.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 139, pl. 21, fig. 12 [as var. *acuta*], fig. 13.—BOYER, Diat. Philadelphia, 1916, p. 94, pl. 26, fig. 17, pl. 40, fig. 9.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 75, pl. 8, figs. 305-311.—BOYER, Syn. N. American Diat., Proc. Philadelphia Acad. Nat. Sci., vol. 79, 1927, Suppl. p. 397.—HUSTEDT, Süsswass.-Flora Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 299, fig. 513.

Pinnularia radiosa (KÜTZING), W. SMITH, Syn. Brit. Diat., vol. 2, 1856, p. 56, pl. 17, figs. 171, 173 [as var. *acuta*].—RABENHORST, Süssw. Diat., 1853, p. 43, pl. 6, fig. 9.

Navicula acuta KÜTZING, Bacill., 1844, p. 93, pl. 3, fig. 69.

This very common fresh-water diatom is almost world wide in its distribution. It is by far the most abundant *Navicula* in the Wallace county deposit. Numerous varieties have been named; usually they have been based on slight alteration of the length-breadth relationship. Under low power or insufficient numerical aperture the markings appear to be smooth bars, but when properly resolved they are found to be punctate as shown in the photograph reproduced herewith.

Navicula tuscula Ehrenberg.

(Plate XXXIII, Figure 6.)

Navicula (*Pinnularia*) *tuscula* EHRENBERG, Ber. Akad. Wiss. Berlin, 1840, p. 215.

Stauroptera tuscula EHRENBERG, Mikrog., 1854, pl. 6, I, fig. 13 *a*.

Navicula tuscula EHRENBERG, VAN HEURCK, Syn. Diat. Belgique, 1880, p. 95, pl. 10, fig. 14.—WOLLE, Diat. N. America, 1890, pl. 32, fig. 10.—CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 27, 1895, p. 12.—VAN HEURCK, Treat. Diat., 1896, p. 206, pl. 4, fig. 166.—SCHÖFELDT, Diat. Germaniæ, 1907, p. 160, pl. 11, fig. 178.—MIGULA, Krypt.-Flora, vol. 2, pt. 1, 1907, p. 259, pl. 7 J, fig. 11.—HÜSTEDT, Süsswass.-Diat. Deutschlands, 1909, p. 40, pl. 8, fig. 14.—HUSTEDT, in SCHMIDT, Atlas Diat. pl. 272, 1911, figs. 23-27.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 142, pl. 21, fig. 23.—MAYER, Ber. Naturwiss. Ver. Regensburg, vol. 14, 1912 [1913], p. 162, pl. 25, figs. 9, 9*a*.—BOYER, Proc. Philadelphia Acad. Nat. Sci., vol. 79 Suppl. 1927, p. 385.—HUSTEDT, Süsswass.-Flora Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 308, figs. 552, 553.

Stauroneis punctata KÜTZING, Bacill., 1844, p. 106, pl. 21, fig. 9.—W. SMITH, Syn. Brit. Diat., vol. 1, 1853, p. 61, pl. 19, fig. 189.—BRUN, Diat. Alps Jura, 1880, p. 9, pl. 9, fig. 4.—WOLLE, Diat. N. America, 1890, pl. 8, fig. 1.

Navicula punctata (KÜTZING), DONKIN, Brit. Diat., 1871, p. 36, pl. 5, fig. 12.

Stauroptera punctata (KÜTZING), RABENHORST, Süssw. Diat., 1853, p. 50, pl. 9, fig. 11.

Very few specimens of this small, beautifully marked species were found in the Wallace county material. The form is widely distributed in Europe, but apparently is less common in America. Boyer recorded it from as far west as Michigan, Illinois and Alberta.

Nitzschia dubia W. Smith.

(Plate XXXIV, Figure 4.)

Nitzschia dubia W. SMITH, Syn. Brit. Diat., vol. 1, 1853, p. 41, pl. 13, fig. 112.—VAN HEURCK, Syn. Diat. Belgique, 1881, p. 174, pl. 59, figs. 9-12.—SCHÖNFELDT, Diat. Germaniæ, 1907, p. 318, pl. 14, fig. 268.—HUSTEDT, Süssw. Diat. Deutschlands, 1909, p. 60, pl. 9, fig. 10. —MAYER, Ber. Naturw. Ver. Regensburg, vol. 14, 1912 [1913], p. 299, pl. 13, fig. 36; pl. 16, fig. 11.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 206, pl. 37, fig. 1.—BOYER, Diat. Philadelphia, 1916, p. 118, pl. 39, fig. 5.—HUDSTEDT, in SCHMIDT, Atlas Diat. pl. 346, 1922, figs. 6, 7.—BOYER, Proc. Acad. Nat. Sci. Philadelphia, vol. 79, 1927 Suppl., p. 503.— HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 403, fig. 770.

Homeocladia dubia (W. SMITH), ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 138, pl. 19, fig. 725.

The specimens from the Wallace county, Kansas, samples fall within the limits of size given for *N. dubia* by Hustedt and Boyer, but in shape they more closely approach *N. commutata* Grunow (1880), *N. stagnorum* Rabenhorst (1856), and *N. thermalis* Kützing (1844). All of these form a closely connected group called "dubiæ" by Grunow, and it may well be that they are merely modifications of one plastic species although they have been generally kept distinct. Another name is hardly warranted in spite of the fact that the specimens with which we are dealing are intermediate. The ends are symmetrically attenuated in most of the Kansas specimens, yet some show a tendency to be "hook-shaped" as shown in the figure in Schmidt's Atlas.

Pinnularia divergentissima (Grunow).

(Plate XXXIII, Figure 4.)

Navicula divergentissima GRUNOW, in VAN HUERCK, Syn. Diat. Belgique, 1880, pl. 6, fig. 32.

Navicula nodulosa (BREBISSON), LAGERSTEDT, Bih. Sven. Vet. Akad. Handl., vol. 1, No. 14, 1873, p. 22, pl. 2, fig. 2.

Pinnularia divergentissima (GRUNOW), CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 27, 1895, p. 77.—HUSTEDT, in SCHMIDT, Atlas Diat., pl. 313, 1914, figs. 15, 16.—BOYER, Proc. Acad. Nat. Sci. Philadelphia, vol. 79, 1927 Suppl., p. 436.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 320, fig. 581.

This little species has always been considered characteristic of the far north and alpine regions; it is therefore of unusual interest to find it in a Pliocene deposit, such as that in Wallace county, Kansas, where it is not at all uncommon. It is so highly distinctive that there is practically no chance that it would be mistaken for any other species.

Pinnularia microstauron (Ehrenberg).

(Plate XXXIII, Figure 3.)

Stauroptera microstauron EHRENBERG, Abh. Akad. Wiss. Berlin, 1841 (1843), pl. 1, IV, fig. 1; pl. 4, II, fig. 2.

Pinnularia microstauron (EHRENBERG), CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 27, 1895, p. 77.—MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 161, pl. 28, figs. 1, 2. —HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 320, figs. 582-585; [with vars.].

Stauroneis microstauron (EHRENBERG), KÜTZING, Bacill., 1844, p. 106, pl. 29, fig. 13.

Navicula brebissonii KÜTZING, Bacill., 1844, p. 93, pl. 3, fig. 49.—SCHMIDT, Atlas Diat., pl. 44, 1876, figs. 17, 18.—VAN HEURCK, Syn. Diat. Belgique, 1880, pl. 5, figs. 7-9; [with vars.].

Pinnularia brebissonii (KÜTZING), CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 27, 1895, p. 78.

The form of this variable species which was found in the Wallace county, Kansas, samples is that which is usually placed under the name *brebissonii* Kützing. Hustedt has held that it is not specifically separable from *microstauron*, and a somewhat cursory examination of the literature bears out his statements. The *brebissonii* form, however, is most abundant in high altitudes or latitudes. Cleve stated regarding *brebissonii* that it is a "very variable species, closely connected with *P. divergens* and with *microstauron*"; also that it is allied to *P. appendiculata*. Evidently there is opportunity here for some very helpful consolidation of species-names.

Pinnularia nobilis Ehrenberg.

(Plate XXXIII, Figure 5.)

Pinnularia nobilis EHRENBERG, Ber. Akad. Wiss. Berlin, 1840, p. 214.—EHRENBERG, Abh. Akad. Wiss. Berlin, 1841 [1843], pl. 2, I, fig. 25; pl. 2, II, fig. 3.—W. SMITH, Syn. Brit. Diat., vol. 1, 1853, p. 52, pl. 17, fig. 161.—CLEVE, Kongl. Sven. Vet. Akad. Handl., vol. 27, 1895, p. 92.—SCHÖNFELDT, Diat. Germaniæ, 1907, p. 178, pl. 12, fig. 213.—MAYER, Ber. Naturw. Ver. Regensburg, vol. 14, 1912 [1913], p. 215, pl. 8, fig. 1, pl. 29, figs. 1, 2.— MEISTER, Beit. Krypt.-Flora, Schweiz, vol. 4, 1912, p. 149, pl. 23, fig. 1.—BOYER, Diat. Philadelphia, 1916, p. 103, pl. 28, fig. 1.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 337, fig. 619.

Navicula nobilis (EHRENBERG), KÜTZING, Bacill., 1844, p. 98, pl. 4, fig. 24.—DONKIN, Brit. Diat., 1871, p. 68, pl. 11, fig. 1.—SCHMIDT, Atlas Diat., pl. 43, 1876, fig. 1.—VAN HEURCK, Syn. Diat. Belgique, 1880, p. 73, pl. 5, fig. 2.—WOLLE, Diat. N. America, 1890, pl. 13, figs. 2, 4, 6.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 64, pl. 6, figs. 178-182.

A very few specimens of this large diatom were found in the Wallace county samples. Evidently it was rare at that locality because fragments are not present in noticeable numbers. There appears to be intergradation among the large heavy species of *Pinnularia* and sometimes it is extremely difficult to decide upon the proper name to use. If, as seems probable, the group became an inhabitant of fresh waters at about the close of the Miocene or early in the

Pliocene then a comparison of specimens from lakes of various dates should enable the evolution of the forms to be traced. It is believed that a search with this in mind would prove successful.

Rhopalodia gibba (Ehrenberg).

(Plate XXXIV, Figures 2, 3.)

Navicula gibba EHRENBERG, Infus. 1838, p. 184, pl. 13, fig. 19.

Epithemia gibba KÜTZING, Bacill. 1844, p. 35, pl. 4, fig. 22.—W. SMITH, Syn. Brit. Diat., vol. 1, 1853, p. 15, pl. 1, fig. 13.—BRUN, Diat. Alps, Jura, 1880, p. 44, pl. 2, fig. 14.—VAN HEURCK, Syn. Diat. Belgique, 1881, p. 139, pl. 32, figs. 1, 2.—WOLLE, Diat. N. America, 1890, pl. 35, figs. 1, 3, 8, 9.—VAN HEURCK, Treat. Diat., 1896, p. 296, pl. 9, figs. 351-354.

Eunotia gibba EHRENBERG, Abh. Akad. Wiss. Berlin, 1841 [1843], p. 3, pl. 1, fig. 39.—BAILEY in FREMONT, Rept. Explor. Exp. 1842-1844 [1845], p. 302, pl. 5, figs. 4, 5.

Rhopalodia gibba (EHRENBERG), MÜLLER, Englers Bot. Jahrb., vol. 22, 1895, p. 65.—HUSTEDT in SCHMIDT, Atlas Diat. pl. 253, 1905, figs. 1-17.—SCHÖNFELDT, Diat. Germaniæ, 1907, p. 206, pl. 14, figs. 254, 255.—HUSTEDT, Süssw.-Diat. Deutschlands, 1909, p. 58, pl. 7, figs. 24, 26.—MEISTER, Beit, Krypt.-Flora, Schweiz, vol. 4, 1912, p. 200, pl. 35, fig. 6.—MAYER, Ber. Naturw. Ver. Regensburg, vol. 14, 1912 [1913], pp. 277-279, pl. 5, figs. 32-39, pl. 18, figs. 15, 16.—BOYER, Diat. Philadelphia, 1916, p. 112, pl. 31, fig. 23.—HUSTEDT, Süssw.-Flora, Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 390, fig. 740.

Cystopleura gibba (EHRENBERG), KUNTZE, Rev. Gen. Plant., vol. 2, 1891, p. 891.—MANN, Cont. U. S. Nat. Herb., vol. 10, pt. 5, 1907, p. 377.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 127, pl. 17, figs. 653-654.

Very few individuals of this distinctive form were seen in the Wallace county samples, although it is very common in most fresh waters at the present time. It has been assigned a place in numerous genera, but Müller's action in creating the new name *Rhopalodia* as distinct from *Epithemia* has had a stabilizing influence. The substitution of *Cystopleura* for the latter was based upon a supposed previous use of the name by Blume in 1826 in Botany.

Synedra ulna (Nitzsch).

(Plate XXXIV, Figure 6.)

Bacillaria ulna NITZSCH, Beiträge z. Infus. Neue Schrift. Naturf. Ges. Halle, vol. 3, Heft 1, 1817, p. 99, pl. 1, figs. 1, 2.

Synedra ulna (NITZSCH), EHRENBERG, Infus., 1938, p. 211.—KÜTZING, Bacill., 1844, p. 66, pl. 20, fig. 38.—RABENHORST, Süssw. Diat., 1853, p. 54, pl. 4, fig. 4.—W. SMITH, Syn. Brit. Diat., vol 1, 1853, p. 71, pl. 11, figs. 90, 91, 95.—RALFS in PRITCHARD, Hist. Infus. Ed. 4, 1861, p. 786, pl. 10, fig. 184.—BRUN, Diat. Alps, Jura, 1880, p. 125, pl. 6, fig. 20.—VAN HEURCK, Syn. Diat. Belgique, 1881, p. 150, pl. 38, fig. 7.—WOLLE, Diat. N. America, 1890, pl. 41, fig. 31.—SCHÖNFELDT, Diat. Germaniæ, 1907, p. 105, pl. 5, figs. 41, 42.—MIGULA, Krypt.-Flora, vol. 2, pt. 1, 1907, p. 193, pl. 11, figs. 14-16.—HUSTEDT, Süssw. Diat. Deutschlands, 1909, p. 21, pl. 3, figs. 16, 19.—MEISTER, Beit. Krypt.-Flora d. Schweiz, vol. 4, 1912, p. 71, pl. 7, figs. 1-3.—MAYER, Ber. Naturwiss. Ver. Regenburg, vol. 14, 1912 [1913], pp. 47-50; pl. 5, fig. 43, pl. 14, fig. 28; pl. 15, figs. 27-29, 31; pl. 26, figs. 6-8; pl. 30, fig. 12.—HUSTEDT in SCHMIDT, Atlas Diat., pls. 301, 302, 303, 1914 [with vars.].—BOYER, Diat. Philadelphia, 1916, p. 47, pl. 11, figs. 4, 7.—ELMORE, Univ. Nebraska Studies, vol. 21, 1921, p. 55, pl. 3, figs. 116-130; pl. 4, figs. 131-139.—BOYER, Proc. Acad. Nat. Sci. Philadelphia, vol. 78, 1926 [1927] Suppl., p. 198.—HUSTEDT, Süsswass.-Flora Mit.-Europas, Heft 10, Bacill. (Diat.), 1930, p. 151, figs. 158-168 [with vars.].

The above is a very fragmental synonymy of this well-known diatom. No attempt has been made to disentangle the large number of synonyms and the varietal names which have been used. Chase (Ms. index) listed no less than 18 of the latter in 1907. The species is extremely variable, particularly in shape and size. The blank space in the center may or may not be present. Sporangial forms, being more or less spatulate, have given rise to several names.

The samples from Wallace county, Kansas, contain considerable numbers of specimens which usually are more or less deformed or broken from formation pressure. The individuals are perhaps somewhat longer than the average living at the present time, and variation, as usual, is very great.

EXPLANATION OF PLATES.

PLATE XXXI.

FIG. 1. *Amphora reinholdi* Hanna, n. sp. × 1419. Length, .0472 mm.; width, .018 mm. Holotype, No. 1.

FIG. 2. *Amphora veneta* Kützing. × 1421. Length, .0380 mm.; width, .0070 mm. Plesiotype, No. 2.

FIG. 3. *Anomoeoneis sphærophora* (Ehrenberg). × 712. Length, .0944 mm.; width, .0283 mm. Plesiotype, No. 27.

FIG. 4. *Anomoeoneis sphærophora* (Ehrenberg). × 1423. Length, .0583 mm.; width, .0160 mm. Plesiotype, No. 3.

FIG. 5. *Cymbella parva* W. Smith. × 1608. Length, .0516 mm.; width, .0120 mm. Plesiotype, No. 10.

FIG. 6. *Cyclotella kansasensis* Hanna, n. sp. × 2411. Diam. .0141 mm. Holotype, No. 6.

FIG. 7. *Cocconeis placentula* Ehrenberg, inferior valve. × 1512. Length, .0390 mm.; width, .0259 mm. Plesiotype, No. 5.

FIG. 8. *Cocconeis placentula* Ehrenberg; superior valve. × 1950. Length, .0346 mm.; width, .0241 mm. Plesiotype, No. 4.

FIG. 9. *Cymbella aspera* (Ehrenberg). × 1611. Length, .0546 mm.; width, .0167 mm. Plesiotype, No. 7.

All of the diatoms illustrated on this plate are from sec. 11, T. 11 S., R. 38 W., Wallace county, Kansas, except figure 3, which is from sec. 29, T. 12 S., R. 41 W.

PLATE XXXI.

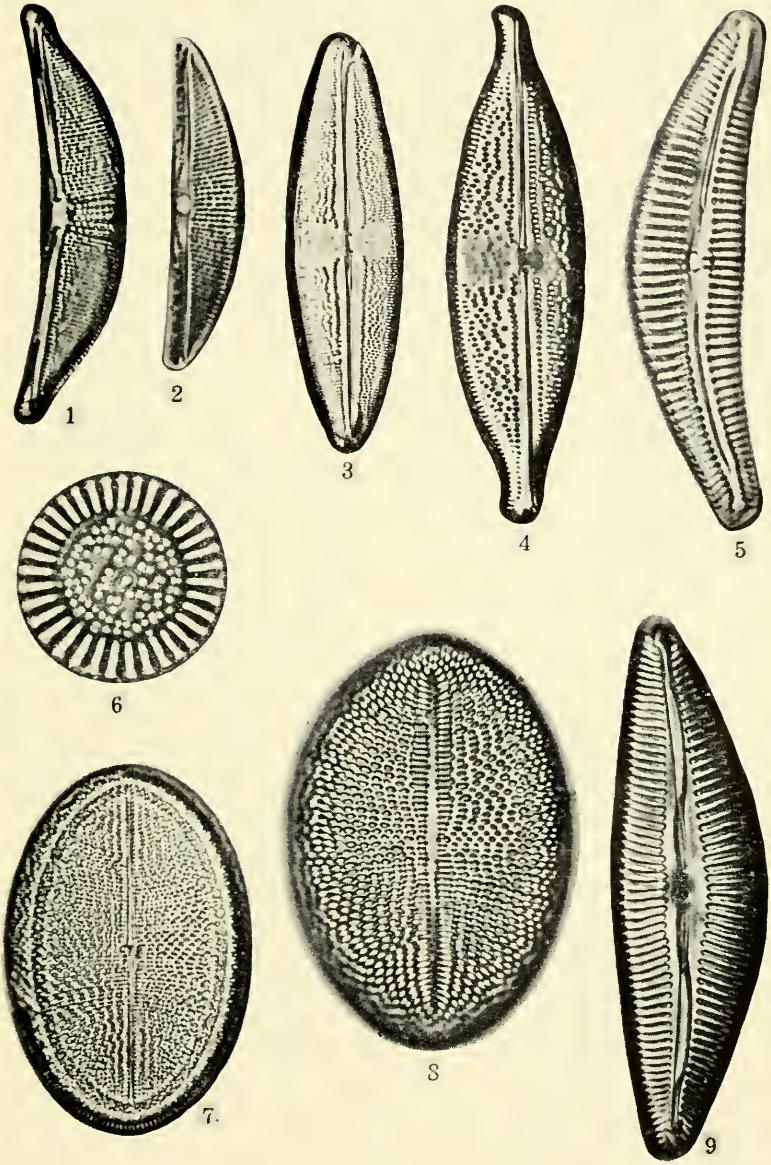

PLATE XXXII.

FIG. 1. *Cymbella lanceolata* (Ehrenberg). × 998. Length, .1152 mm.; width, .0220 mm. Plesiotype, No. 8.

FIG. 2. *Cymbella ventricosa* Kützing. × 1616. Length, .0365 mm.; width, .0138 mm. Plesiotype, No. 11.

FIG. 3. *Cymatopleura solea* (Brebisson). × 894. Length, .0984 mm.; width, .0282 mm. (at ends). Plesiotype, No. 23.

FIG. 4. *Cymbella mexicana* (Ehrenberg). × 1133. Length, .0829 mm.; width, .0215 mm. Plesiotype, No. 9.

FIG. 5. *Denticula elegans* Kützing. × 1555. Length, .0376 mm.; width, .0067 mm. Plesiotype, No. 12.

FIG. 6. *Denticula elegans* Kützing, girdle band. × 1366. Length, .0344 mm.; width, .0063 mm. Plesiotype, No. 25.

FIG. 7. *Fragilaria pinnata* (Ehrenberg), chain of frustules. × 968. Length, .0346 mm.; width, .0118 mm. Plesiotype, No. 32.

FIG. 8. *Fragilaria pinnata* (Ehrenberg). × 1347. Plesiotype, No. 20a.

FIG. 9. *Fragilaria pinnata* (Ehrenberg). × 1390. Length, .0325 mm.; width, .0072 mm. Plesiotype, No. 24.

FIG. 10. *Fragilaria pinnata* (Ehrenberg). × 958. Length, .0407 mm.; width, .0075 mm. Plesiotype, No. 29.

FIG. 11. *Fragilaria pinnata* (Ehrenberg). × 989. Length, .0273 mm.; width, .0073 mm. Plesiotype, No. 30.

FIG. 12. *Fragilaria pinnata* (Ehrenberg), side view of frustule. × 952. Length, .0252 mm.; width, .0123 mm. Plesiotype, No. 31.

FIG. 13. *Gomphonema semiapertum* Grunow. × 1236. Length, .0562 mm.; width, .0180 mm. Plesiotype, No. 14.

FIG. 14. *Gomphonema acuminatum* Ehrenberg. × 1243. Length, .0563 mm.; width, .0085 mm. Plesiotype, No. 13.

Figures 1, 2, 4, 5, 8, 13 and 14 are from sec. 11, T. 11 S., R. 38 W., Wallace county, Kansas; the remainder are from sec. 29, T. 12 S., R. 41 W.

PLATE XXXII.

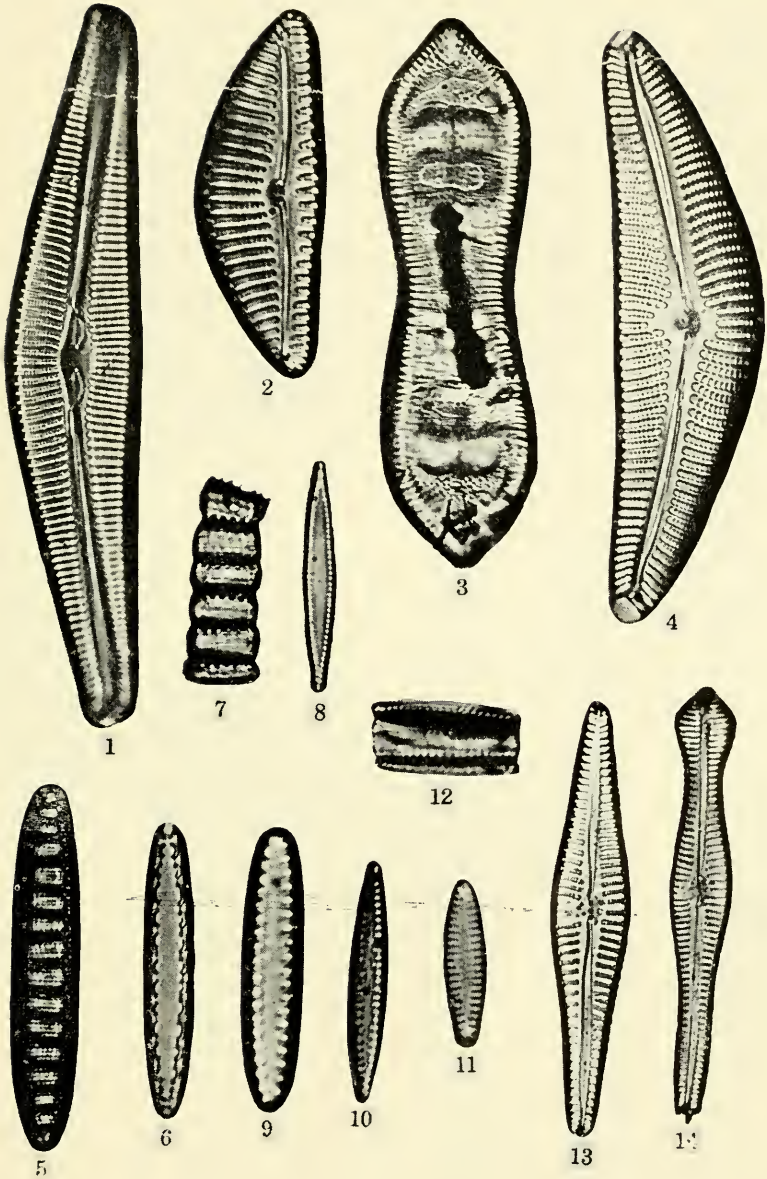

PLATE XXXIII.

FIG. 1. *Navicula radiosa* Kützing. ×838. Length, .1253 mm.; width, .0241 mm. Plesiotype, No. 17.

FIG. 2. *Navicula radiosa* Kützing. Enlarged central section to show finer markings. ×1286. Plesiotype, No. 17.

FIG. 3. *Pinnularia microstauron* (Ehrenberg). ×1347. Length, .0475 mm.; width, .0180 mm. Plesiotype, No. 20.

FIG. 4. *Pinnularia divergentissima* (Grunow). ×960. Length, .0583 mm.; width, .0116 mm. Plesiotype, No. 28.

FIG. 5. *Pinnularia nobilis* Ehrenberg. ×415. Length, .2332 mm.; width, .0361 mm. Plesiotype, No. 33.

FIG. 6. *Navicula tuscula* Ehrenberg. ×1521. Length, .0562 mm.; width, .0221 mm. Plesiotype, No. 18.

FIG. 7. *Navicula pauper* Mann. ×1003. Length, .1036 mm.; width, .0136 mm. Plesiotype, No. 16.

FIG. 8. *Cymbella cesatii* Rabenhorst. ×1003. Length, .0972 mm.; width, .0153 mm. Plesiotype, No. 15.

FIG. 9. *Navicula pauper* Mann; enlargement of end to show characters of raphe. ×2006. Plesiotype, No. 16.

All of the diatoms illustrated on this plate are from sec. 11, T. 11 S., R. 38 W., Wallace county, Kansas, except figures 4 and 5, which are from sec. 29. T. 12 S., R. 41 W.

PLATE XXXIII.

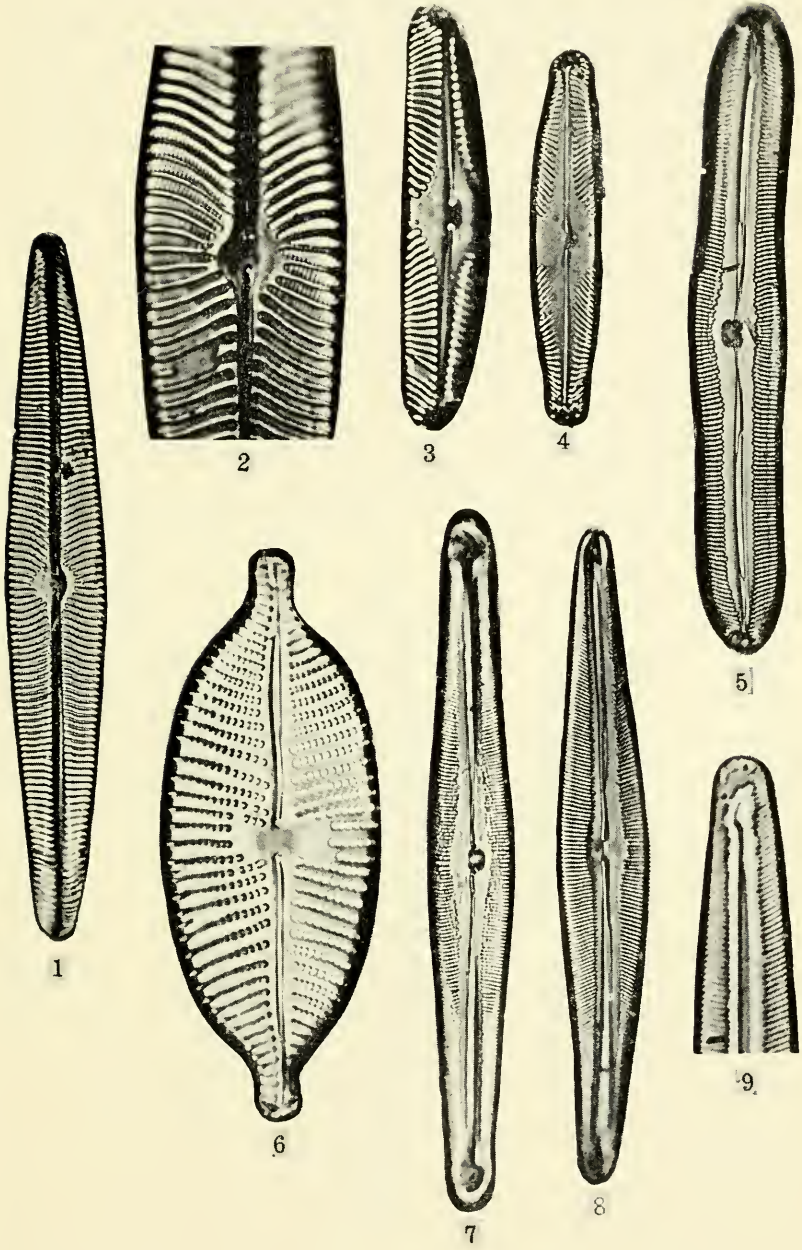

PLATE XXXIV.

FIG. 1. General view of strewn material. × 300.

FIG. 2. *Rhopalodia gibba* (Ehrenberg). × 985. Length, .1086 mm.; width, .0090 mm. Plesiotype, No. 21.

FIG. 3. *Rhopalodia gibba* (Ehrenberg); enlarged central area to show nature of finer markings. × 1666. Plesiotype, No. 21.

FIG. 4. *Nitzschia dubia* W. Smith. × 1522. Length, .0591 mm.; width, .0180 mm. Plesiotype, No. 19. Another specimen on the same slide measures, length, .0812 mm.; width, .0114 mm.

FIG. 5. *Navicula gibbula* Cleve. × 1983. Length, .0353 mm.; width, .0116 mm. Plesiotype, No. 26.

FIG. 6. *Synedra ulna* (Nitzsch). × 533. Length, .4020 mm.; width, .0075 mm. Plesiotype, No. 22. If the entire diatom were enlarged to the same scale the length of the photograph would be 214 mm.; (8 inches).

All of the diatoms illustrated on this plate are from sec. 11, T. 11 S., R. 38 W., Wallace county, Kansas, except figure 5, which is from sec. 29, T. 12 S., R. 41 W.

PLATE XXXIV.

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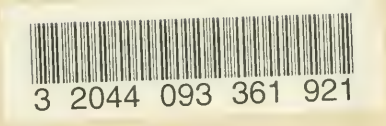
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